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MAY 1926

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PUBLISHED MONTHLY BY THE
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 WEST 39TH ST· NEW YORK CITY

American Institute of Electrical Engineers

COMING MEETINGS

Annual Business Meeting, New York, N. Y., May 21
Annual Convention, White Sulphur Springs, W. Va., June 21-25
Pacific Coast Convention, Salt Lake City, Utah, September 7-10

Regional Meetings

Great Lakes District, Madison, Wis., May 6-7
Northeastern District, Niagara Falls, May 26-28

MEETINGS OF OTHER SOCIETIES

National Fire Protection Association, Atlantic City, May 10-13
National Electric Light Association, Atlantic City, May 17-21
Electric Power Club, The Homestead, Hot Springs, Va.
The American Physical Society, Oakland, California, June 17
The American Society of Civil Engineers, Seattle, Wash., July 14-16

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Journal of the A. I. E. E.

Devoted to the advancement of the theory and practise of electrical engineering and the allied arts and sciences

Vol. XLV MAY, 1926 Number 5

Address of Welcome to the I. E. C.*

Once upon a time a Greek philosopher said that to "know thyself" is the first step to wisdom. He might have added that to "know thy neighbour" is the second step to wisdom. I learned this second step when still a boy in my native village.

There are some twelve peasant villages within a circle of a radius of ten miles, of which my native village is the center. Five different races live in these villages: Serbs, Slovaks, Rumanians, Germans, and Hungarians. These simple peasant folk meet each other regularly on market days. Each village has one or two market days during the year, and on such days it is visited by the peasants of the neighboring villages. There the different races meet and greet each other by the Serbian word "komshiya," neighbour. This is the most popular word in their interracial vocabulary. These peasants learn that without the komshiya, the neighbour, one cannot exchange the things which he has for the things that he has not; and above all, one cannot enrich his own experience by the experience of his neighbors. This knowledge is a great help to him who strives to reach that lofty level which is described in the words: "Love thy neighbour as thyself." I do not say that these simple peasant folk in my native district ever reached that lofty level, but I do say that I never saw a small district which looks like glacial moraine of different races where the Serbs, Slovaks, Rumanians, Hungarians, and Germans are so sincerely attached to one another. With them, the difference in breed and creed counts for very little. but identity in the aims of their simple lives counts for very much. This identity of aims acts like a catalyst; it brings their hearts into closer contact and convinces them that they all have the same human hearts and souls in spite of the difference in race and religion.

As I look around this festive board and remember that our beloved guests represent so many different nations and religions I am reminded of my childhood days when I saw my father, an enthusiastic Serb, shaking hands with Hungarians, Slovaks, Germans, and Rumanians from neighboring villages, greeting them with the magic word komshiya, neighbour. I extend to you the same greeting today: Welcome komshiya, welcome our dearly beloved neighbours! Nay, you are even closer to us than neighbours. Do not the names Volt, Ohm, Ampère, Farad, Henry and Gauss; Watt, Coulomb, and Joule, remind us that we all have the same household gods, the same Lares and Penates? And, besides, do we not worship at the altars of the same patron saints: Kelvin, Helmholtz, Maxwell, and Hertz; Siemens, Gramme, and Pacinotti?

We are, indeed, members of the same family, and every meeting of the International Electrotechnical Commission looks more and more like a family reunion. I wish that the Mayor and the Board of Alderman of New York were with us today and that the Congressmen and Senators were with us to study our reunion and learn that scientists and engineers have discovered a secret greater than any secret in science; namely, the secret of laying a true foundation for a League of Nations. Let others follow and the world will soon become a Paradise Regained.

M. I. PUPIN.

*At the Luncheon in honor of the International Electrotechnical Commission, April 14, 1426.

Some Leaders of the A. I. E. E.

PAUL MARTYN LINCOLN, from 1914-1915 twenty-seventh president of the A. I. E. E., was born Jan. 1, 1870 in Norwood, Michigan. In 1880 the family moved to Painsville, Ohio, through the high schools of which town Mr. Lincoln received his early schooling. In 1888, a year in the Western Reserve University, Cleveland, convinced him that his capabilities inclined more to the technical than the classical and upon completion of one year at the Western Reserve University, he entered Ohio State University, from which he received his degree of M. E. in Electrical Engineering June 1892. Immediately upon the close of his final semester, he engaged with the Short Electric Company, of Cleveland, but in December of that year, went to the Westinghouse Electric and Mfg. Co., Pittsburgh, to take up important work for them. Two and a half years later he was chosen electrical superintendent in charge of the water power development of Niagara Falls for the Niagara Falls Power Company. This was the beginning of modern hydroelectric development, and the amount of power generated, transmitted and distributed by this first plant was so far in excess of anything accomplished up to that date as to make it unique, with new problems involved in its progress constantly arising to be solved. In 1902, Mr. Lincoln returned to the Westinghouse Company and for six years was in charge of their Power Division of the Engineering Department. 1910 he was appointed general engineer

for the Company, in which capacity he served until he tendered his resignation in 1919.

From 1911 to 1915, Mr. Lincoln was head of the electrical school at the University of Pittsburgh, still carrying on his work with the Westinghouse Electric & Mfg. Co. while caring for his educational responsibilities. The Lincoln Electric Company had been organized by an older brother in 1894 and it was to join this brother that Mr. Lincoln's resignation was tendered to the Westinghouse Company. He remained with his brother until taking up his duties as director of the School of Electrical Engineering, Cornell University, November 1, 1922.

Beside serving the Institute as its President, Mr. Lincoln was, for five consecutive years, from 1909 to 1914, chairman of its Sections Committee, performing a most efficient service to the professional world in this capacity. The synchroscope, a device now in universal use wherever a-c. machines are parallelled, was one of his inventions for which in 1902 he received the John Scott Medal award from the City of Philadelphia upon the recommendation of the Franklin Institute.

Street Lighting

Street lighting has been a problem ever since men began to herd together in cities. At first the problem was solved by each citizen who ventured out at night carrying a lantern or hiring a link boy to carry a torch before him.

This didn't amount to much as protection from highwaymen, although it did help some in getting over, around, or through the mud puddles. During that period the easiest and most popular solution of the street lighting problem was to stay at home after dark.

By and by came oil lamps, stuck on poles, to help out the hand lanterns. Then gas lamps took the place of oil; and so, by degrees, we come to our modern age of electric lighting.

It is well within the truth to say that, even in America, street lighting is still in a primitive stage. We have of course our "White Way" in every city of any importance, but once outside this area, the streets are often dismal and dangerous after dark. The average community seems to spend just enough on street lighting to make the darkness more confusing. There is a popular notion that street illumination costs much money, but the latest investigation shows that the per capita cost is only about 75 cents a year.

Scientific and adequate street lighting is a social question of paramount importance in the modern world.

First of all we have the fact of vastly accelerated out-of-door movement among all classes of people. Shut in by day, the masses and classes alike are impelled to stir abroad at night. In the threater and shopping district, it has become the recognized practise to make the streets as light as day. What the community fails to furnish, the stores and places of amusement make up as part of their sales and advertising budget.

There are three reasons, among many others, why every city and town and many country roads must from now on be properly lighted.

First, the safety, happiness and comfort of all the people demand it.

Second, the enormous increase in power transportation brings us to the point where traffic growth must cease unless folks can see where they are going. This refers to pedestrians equally with those in automobiles, busses and street cars.

Third, according to an ancient scripture, where the carcass is the birds will gather together. With the streets thronged at night at the centers, it means that the *home* streets, roads and byways will all have belated travellers at night. This brings the hold-up man and other criminals to their harvest. Good street-lighting is second only to a good police force as a crime deterrent. Men love darkness rather than light when their deeds are evil. Crime diminishes as light increases.

Recognizing the great social value of good street-lighting, the scientific and engineering resources of the leading lighting laboratories have been directed towards a solution of this problem with extraordinary success. We have the lamps and the electric energy and we know how to use both to the best advantage in street-lighting. When the people wake up to the necessity of proper street-lighting, half the job will have been done.—*Light*, March, 1926.

Distribution Networks

After much debate the system most favored is the three-phase, four-wire alternating-current network for the supply of light, power or the combination of light and power. But, unfortunately, most services and equipments are 110 volts or 220 volts today, and the electrical relations in the three-phase circuit make it possible only to obtain service at either 115 and 199 volts or 120 and 208 volts with simple transformation ratios. The relative merits of these combinations have been debated thoroughly and especially their effects on service using present standard equipment. No unanimous decision has been reached and both types of networks are in service. Both systems give satisfactory service when standard equipment is used, for, fortunately, lamps may be had at either 115 or 120 volts and single-phase and polyphase motors have tolerances whereby satisfactory operation may be had between, roughly, 110 and 120 volts single-phase and 200 and 240 volts three-phase. But, of course, when operated at points near the tolerance limits the margins of departure from the average motor characteristics are changed, and a design based on either system as a standard would have a wider field of satisfactory application.—*Electrical World*.

Important Features of a Successful Plan for Rural Electrification

BY G. G. POST[1]
Associate, A. I. E. E.

Synopsis.—Electric service in rural districts is considered to be a necessity, and a plan for bringing this about in southeastern Wisconsin is outlined in this paper. The main features discussed are: (1) organization for the work, (2) rural rates and financing of line extensions, and (3), advertising and education. A type of economical line construction which will render reliable service is described. The outstanding feature of this line construction is the use of 300-ft. spans. Interesting data, obtained in a survey of a number of rural lines, are presented. The paper shows that in the territory served there were 2740 farms receiving service under the rural rate on January 1, 1926.

It also shows that the general plan, which has been followed since 1920, encourages the extension of lines and extensive use of the service after farms have been connected.

General

The necessity for rural electrification and its economic importance have been widely discussed and there is general agreement that electric service should be made available to our rural population as rapidly as possible. To accomplish results in this direction requires that definite and effective plans be developed and adopted by those electric service supply companies which are in position to serve rural territory.

Plans for bringing about rural electrification vary considerably. Utilities in quite similar territories often differ on important points. Then, there are differences inherent in the territory to be served, such as the density of population and the farming resources, depending in large measure upon productivity of the soil and general knowledge of farming methods. It is not the writer's purpose to discuss or compare various plans but rather to outline a certain plan which has been worked out on a fairly extensive scale and has proved to be effective.

The territory in which these plans are in operation includes 11 counties or portions of counties in eastern and southeastern Wisconsin served by The Milwaukee Electric Railway & Light Company and its associated companies—the Wisconsin Gas and Electric Company and the Badger Public Service Company. Fig. 1 is a general map of the lines of these companies. There is a total of 21,000 farms in the territory.

Organization for the Work

The most essential thing in a rural electrification plan is a proper organization to carry on the work. No company would consider the prosecution of a new and important undertaking without putting some one in charge and making that person responsible for the results.

Rural electrification is a new and important undertaking. It covers a field differing from any that has ever been covered before by electric utilities. If rural electrification is to succeed as fully as it should, the utilities must give it the same careful thought and effort they have given other important activities that have confronted them in the past and that have been successfully handled. The only way to do this is to establish a rural service commercial division, or department composed of a rural agent and such assistants or rural

Fig. 1—Distribution Lines of the Milwaukee Electric Railway and Light Company and Associated Companies

service salesmen as may be required, to adequately promote the use of electric service and electric equipment by the farmers of the territory the utility serves. The Milwaukee Electric Railway & Light Company employs a rural agent and from four to six rural service salesmen. These men have worked on farms, know the language of the farmer, and at the same time are ex

1. Electrical Engineer, The Milwaukee Electric Railway & Light Co., Milwaukee, Wis.

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perienced commercial engineers. They study all phases of the rural electrification problem, take such action as may be necessary to follow up advertising, keep prospective consumers interested in the service, carry on negotiations for line extensions, introduce new uses for the service, and do any other work which the proper conduct of the business requires.

Rural Rates and the Financing of Line Extensions

Before any organization can be effective, a system of rates and a method of financing line extensions, consumers wiring, and equipment must be developed.

It is a sound principle that country dwellers are not much different in their fundamental nature and aspirations than those residing in urban districts and that in establishing rates and line extension policies the same general principles should govern in rural as in urban districts. If it is right and equitable to have the equivalent of a demand charge (active rooms) in residence rates, and if a demand charge in commercial and power rates is right and equitable is it not proper that there should be the equivalent of a demand charge (active rooms and minimum charge per connected h. p.) in the rural rate? Fundamentally, the farm is the farmer's residence and factory and the rate to be equitable must include the characteristics of plain residence rates and those of commercial or power rates. The rate must also be one which will discourage the use of motors of excessive h-p. rating and encourage the consumption of kw-hr. To express it in another way, the rates should encourage the consumer to operate at a high load factor and make the fullest use of the service. With this idea in mind a rural rate, substantially as follows, was developed in 1920:

Rural consumers are defined as consumers generally located outside of the limits of cities and villages who are engaged in farming, stock raising, or dairying.

Rural consumers located upon existing distributing lines or who contribute to the cost of constructing extensions in accordance with the Company's rules and who execute the Company's standard form of rural service contract for a period of not less than two years may purchase single-phase electric service at the following rates.

(*a*) *Service Charge.* Two dollars per month for four or less active rooms plus forty cents per month for each active room in excess of the first four.

Service charge shall include energy consumption equivalent to five kw-hr. per active room per month or not less than 20 kw-hr., in case the active rooms are less than four.

(*b*) *Energy Charge.* Three and one-half cents per kw-hr. for all energy consumed in excess of five kw-hr. per active room, or in excess of 20 kw-hr. in case the active rooms are less than four.

The number of active rooms shall be computed on the following basis:

(1) All rooms contained in the residence shall be counted as active, except bathrooms, basements, garrets, closets, halls, pantry, unwired storage rooms, and three rooms used as bedrooms or sleeping quarters but not used for other purposes.

(2) Rural installations having barns, poultry houses, or greenhouses, but not wired, shall have the residence count increased by one active room.

(3) Rural installations having barns, poultry houses, or greenhouses wired, shall have their counts increased by one active room for each separate horse-barn, dairy-barn, poultry house, and greenhouse actually connected to the distribution system and receiving energy.

(4) Sheds or open barns used to shelter live stock, grains, feeds, or machinery (and not regularly used as horse barns or dairy barns), garages, and miscellaneous buildings, even though wired, shall be exempted from the active room count, excepting such garages, blacksmith shops, and other buildings that may be conducted for and open to the general public as repair or service shops. Each building so conducted shall be counted as an active room.

(5) A barn used as a combination horse and dairy barn shall be counted only as one active room.

(6) Where rural consumers, as herein defined, are located within the limits of cities and villages, such consumers may obtain service on either the rural rate or residence rate applicable in such localities.

The foregoing rate shall apply to all energy used for household purposes, including cooking, and for miscellaneous power purposes, providing the total nominal rated capacity of motors does not exceed three h. p. and providing the motors are not operated between sundown and 11:00 p. m. Service for additional motors will be supplied at the foregoing rates plus an additional charge of fifty cents per month for each h. p. or fraction thereof in excess of three h. p.

The foregoing rate does not include renewals of any incandescent lamps, but is subject to the Company's standard prompt payment discount of five per cent on the first $25.00 and one per cent on amounts in excess of $25.00 on monthly bills paid on or before the last discount date. Bills will be issued as far as practicable 10 days prior to the last discount date.

The gross bills under this schedule may be calculated from the following table.

Monthly Bills for Farm Customers

The minimum charge in this table allows (a) three h. p. in connected motor load and (b) energy consumption of five kw-hr. per active room, or 20 kw-hr. total for less than four rooms.

For connected motor load in excess of three h. p., add 50 cents per month for each h. p. or fraction thereof in excess of three h. p.

For energy consumption, add three and one-half cents for every kw-hr. in excess of five kw-hr. per active room (or 20 kw-hr. total for less than four rooms).

No. of Active Rooms	Kw-Hr. Consumption Allowed on Minimum Charge	Minimum Monthly Charge
4 or less	20	$2.00
5	25	2.40
6	30	2.80
7	35	3.20
8	40	3.60
9	45	4.00
10	50	4.40

As far as the supply company is concerned, there is only one essential difference between rural and urban service, *i. e.*, the greater distances between consumers in the country than in urban territory. This necessitates more line investment per consumer in rural than in urban territory, making it necessary that some means be found for providing for the excess investment.

Before rural service was seriously considered, utility companies found it necessary to devise a plan under which lines could be extended to supply isolated consumers in the fringe surrounding urban territory where the extensions were so long that the revenue would not justify the investment. It became necessary, under such circumstances, for prospective consumers to assist in financing the lines. It was only logical that this principle should be applied in extending lines in rural communities. Consequently the plan was adopted of requiring the prospective consumers to contribute toward the cost of extending the service to them an amount equivalent to the difference between the cost of the extension and the estimated three-years' gross revenue. At the same time provision was made that if other consumers were connected to the extension and it was not necessary for them to contribute toward the cost of their extensions, half of their net bills would be used as a refund to those contributing to the cost of the original extension. Such refunds are discontinued when the original extension has been in service three years, and the total refunds must not exceed the total of the original contributions.

It is usually found that some farmers desire the service more than others, or at least are willing to invest more money in getting it if necessary. Some farmers have been willing to use the service but have been unwilling to contribute anything toward the cost of the line. Others not only are willing to agree to use the service on as extensive a basis as possible, but are willing to contribute a reasonable amount where necessary in order to get the line constructed and the service furnished. It is not possible in these cases to get the farmer consumers on a rural line to bear an equal portion of the investment the company has to make in excess of the amount warranted by the revenue. It has been found necessary to lay the amount to be advanced and the complete proposition, before the group and have them decide among themselves how they will finance the excess cost. One of the farmers, agreeable to both the group and the company, is designated as the official representative of the group and he executes the line extension agreement and turns over to the company the part of the investment required to be advanced by the farmers under the line extension agreement. He may have paid it all himself or he may have collected various parts of it from different farmers. Along with every line-extension agreement there is a blue-print showing the line as constructed and the services connected thereto. This record is carefully preserved and in the future, if there are refunds to the group to be made by the company due to additional consumers coming on the line, they are made to the official representative of the group who executed the line extension agreement and he is responsible for distributing these refunds to the farmers in a manner mutually satisfactory or in accordance with a basis previously agreed upon among themselves.

Although the ownership of lines partially financed by the consumers rests entirely in the utility, the amount contributed is not included in the utility's valuation for rate-making purposes. No special fixed charge is, therefore, included in the rates to cover any extra investment in rural lines and for this reason the monthly charge per kw-hr. is considerably lower than it would be if the utility carried all of the investment.

It must be borne in mind that, ultimately, there will be a vast network of distribution lines serving cities, villages and rural districts alike, and if rural consumers are to remain satisfied there must not be a special fixed charge in their rate to make their cost per kw-hr. higher than that of the urban consumers who may live next to them along the border lines of cities and villages.

Recognizing that it requires a considerable amount of money to contribute toward the cost of lines, to wire farms, and to purchase equipment, a plan has been devised under which the utility advances the money for the purchase of appliances or other equipment and wiring and the rural consumer pays it back on the installment plan in accordance with the terms of certain agreements.

Under the general plan for financing line extensions, farmers are encouraged to install as much equipment as possible so as to increase the gross revenue from the line and cut down the amount which must be contributed toward line extensions. In a good many cases it has been found that this results in the installation of electric ranges or other equipment which would probably not be otherwise installed.

The farmer is thus enabled to make immediate and full use of the service and derive the benefits which electric service always affords.

Advertising and Education

Advertising is just as important in the extension of electric service to the farmers as in any other line of endeavor. The farmer cannot be expected to want it if he is not told about its many benefits. Personal work with the farmers is most effective. The rural agent and his rural service salesmen are most valuable in establishing personal contacts with farmers and acquainting them with all known phases of rural electrification. The efforts of the rural service division are supplemented by the knowledge and experience of the company's regular advertising forces which are especially helpful in advertising in rural papers, in preparing special posters, talking at booster meetings in rural territory, etc. The specific plan adopted is to inform the farmer by all feasible means available as to the special applications and advantages of electric service to each individual farmer. Instead of waiting for the farmers to apply for electric service, the electric service company endeavors to develop the interest of all the farmers in the use of electric service and especially cooperate with those who already have the desire for the service in getting other farmers along the pro-

posed route of the line interested, so that the line may be constructed and the service furnished at the lowest possible cost to any of the farmers. In connection with this work, farmers are being circularized and furnished booklets which show what electric service means to them. Advertisements are being inserted in local newspapers, and demonstrations are being held at various points where an audience of sufficient size to warrant a demonstration and exhibit can be gotten together. At these demonstration meetings well-informed representatives of the company are present, and an effort is made to furnish to the farmers any information desired regarding electric service and electric equipment and how they may be obtained.

The rural service salesmen always stress the point that the utility is not in the business of selling line extensions but rather the service and that it is desirable for the consumer to spend as much as he can afford on equipment which will enable him to make the most use of the service not only in the farm operations but in his home where the convenience of the service is so much appreciated and enjoyed by the housewife.

A roadside sign set up on a farm where a rural line extension is being installed is very helpful in attracting new customers. In some cases, as at the beginning of a line extension where service is available, these signs are illuminated. They are very effective, however, without illumination.

Much effective work is also done by establishing rural electrification booths at state and county fairs. These are strictly educational and informational displays to emphasize to farmers the benefits of the service.

Line Construction

Because of the small number of consumers per mi. of line it is important that the cost of line construction be kept down to the minimum, consistent with reasonable service. This keeps fixed charges within reason and reduces to a minimum the amount which prospective consumers must contribute toward the cost of line extensions.

Utilities should not come to the conclusion that service to farmers can be less reliable than that to the ordinary small city or village. When a farmer installs a range upon which he depends for the cooking of his meals when he installs a milking machine with which he expects to milk the cows, when he installs a heating plant which depends upon electric service for its operation, when he installs a motor-driven pump to furnish water to his stock or for the house, and when he installs other electrically driven equipment upon which his farm processes and operations depend, it is a serious matter if reasonably continuous service is not given and the farmer cannot be expected to electrify his farm if the service is not reliable.

The line construction employed, although it must of necessity be reasonable in cost, must embody all of the features which contribute to make possible safe and continuous operation.

The principal features of the line construction which has been adopted as most reasonable in cost and which at the same time meet the requirements for good service are as follows:

Size of poles..............	30 ft., 7 in. top, (western red cedar)
Spacing of poles...........	300 ft.
Size and kind of conductors	No. 2 A. W. G., A. C. S. R.
Size and kind of crossarms.	3¼ by 4¼ by 5 ft. 7 in. fir
Size and kind of pins......	No. 581 malleable clamp pin (St. Louis Malleable Casting Company)
Insulators................	No. 9404 Ohio Brass (or equivalent)
Operating voltage.........	5000 primary, 120/240 secondary

Every tenth pole an anchor structure.

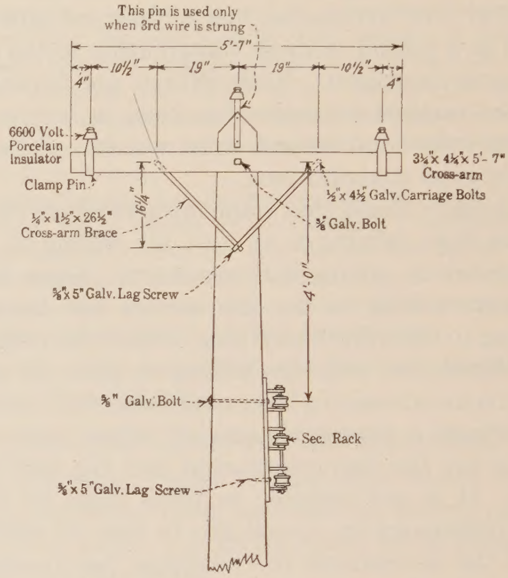

Fig. 2—Arrangement of Pole Top

The details of the construction are shown in Figs. 2, 3, 4, 5, 6, and 7. The cost of a single-phase primary line, exclusive of transformers, lightning arresters, secondary mains, and services is approximately $750 per mi. in country where there is little trouble with trees and where there is neither rock nor too much gravel to interfere with pole setting. If tree conditions are bad or if rock or gravel is encountered, the cost will of necessity be increased. The details of cost are shown in Table I.

That the construction is safe is shown by the following:

Conductor Stresses:

Elastic limit..............................	1860 lb.
Ultimate strength..........................	2660 lb.
Stress at 0 deg. fahr. with ½ in. ice and 8 lb. wind pressure..............................	1860 lb.

Conductor Clearance from Ground:

Clearance at 0 deg. fahr. with ½ in. ice........	19.7 ft.
Clearance required by National Electrical Safety Code..........................	18.0 ft.

Resisting Moments of Poles:
Safe loading of 30-ft., 7-in. top western cedar, 30-in. circumference at ground line........... 17,800 ft-lb.
Required by loading ½-in. ice and 8-lb. wind..... 14,870 ft-lb.
Conductor Spacing:
Provided by this construction (three-phase).... 29½ in.
Required by National Electrical Safety Code for 300-ft. spans........................... 18¾ in.
Pins and Insulators:
Lateral stress with ½ in. ice and 8-lb. wind pressure.................................. 263 lb.
Stress in direction of line (conductors broken)... 1860 lb.
Stress which two pins on anchor structure will safely withstand........................ 1950 lb.
Stress which insulators will withstand.......... 4000 lb.
Crossarms:
Stress in direction of line which single arms will safely withstand........................ 1880 lb.
Stress in direction of line (maximum loading) one conductor broken........................ 1860 lb.

TABLE I

ESTIMATED COST PER MILE FOR THE EXTENSION OF TWO NO. 2 A. C. S. R. USING 300 FOOT SPANS

Material	Unit Cost	Quantity	Amount
No. 2 A. C. S. R..................	$0.0208	10,700 ft.	$222.56
5/16 in. guy wire..................	0.018	440 ft.	7.92
30 ft. western cedar poles..........	7.14	18	128.52
35 ft. western cedar poles..........	11.92	2	23.84
Everstick Anchors.................	1.52	4	6.08
No. 4 X insulators................	0.27	8	2.16
Pole shims (large)................	0.12	16	1.92
2 bolt guy clamps.................	0.42	32	13.44
5 ft. 7 in. cross-arms.............	0.69	20	13.80
Cross-arm braces..................	0.24	32	7.68
No. 581 clamp pins................	0.457	40	18.28
5/8 by 12 in. galvanized machine bolts	0.083	16	1.33
5/8 by 16 in. galvanized machine bolts	0.105	2	0.21
5/8 by 5 in. galvanized lag bolts.....	0.0411	16	0.66
1-1/2 by 4-1/2 in. galvanized carriage bolts..........................	0.0315	32	1.01
6600 volt pin type insulators.........	0.14	40	5.60
Aluminum sleeves (2 sleeves per joint)	0.16	4	0.64
Aluminum armor for insulator ties....	0.35	2.9 lb.	1.02
No. 6 tie wire (annealed aluminum)...	0.33	3.0 lb.	.99
Total Material.........			457.66
Labor			
Pole crew.....................	5.94	12 hrs.	71.42
Line crew.....................	3.75	16 hrs.	60.04
Supervision and engineering.....			19.72
			151.18
Sundries			
Truck........................	0.65	28 hrs.	18.20
Tools and injuries—5 per cent of labor........................			7.43
Right-of-way................			54.08
			79.71
Contingencies			
Grand Total....................			58.35
			$746.90

Note: Pole Work—1 foreman, 1 driver and 6 polemen can set 12 poles per day of 8 hr.
Line Work—1 foreman, 2 linemen and 2 groundmen can install cross-arms, string wire and tie in 1 mi. in 2 days of 8 hr. each.

Where secondary mains are necessary, 30 ft., 6 in., top poles spaced 150 ft. apart are used except for transformer poles which must have not less than 7 in. tops. This permits the use of No. 6 or larger, hard-drawn copper secondary mains installed on racks. All transformer connections are of copper and the copper conductors are connected to the aluminum conductors with approved clamps.

Results Achieved

During the fall and winter of 1925-1926 some interesting data were collected on a few rural lines.

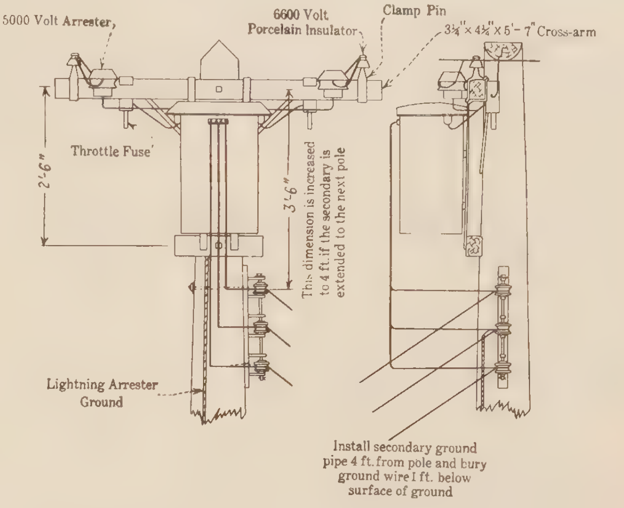

Fig. 3—Transformer Installation Supplying Service Drop

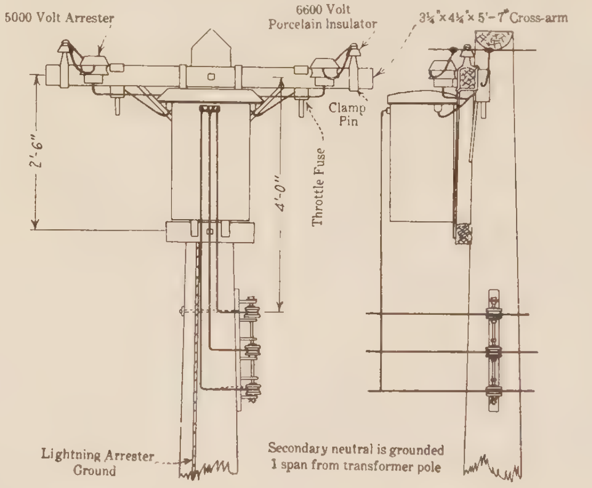

Fig. 4—Transformer Installation Supplying Secondary Main

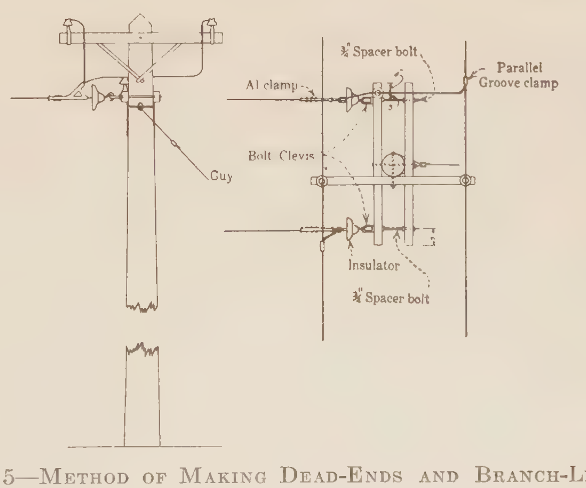

Fig. 5—Method of Making Dead-Ends and Branch-Line Taps

TABLE II
RURAL LINE SURVEY—AVERAGE LINE, TRANSFORMER AND CUSTOMER DATA

	Line No. 1	Line No. 2	Line No. 3	Line No. 4	Line No. 5	Average
Date of special test period	10/23/25 to 10/30/25	1/8/26 to 11/14/26	1/7/26 to 1/13/26	12/17/25 to 12/24/25	1/18/26 to 1/26/26	Winter
Number of customers per line	6	6	13	23	25	14.6
Length of line in mi	0.57	0.75	1.73	4.93	3.70	2.34
Average number of customers per mi	10.5	8.	7.5	4.66	6.75	6.*
Average size of farm served—acres	74.	63.	43.	88.	59.	66.*
Average load applied for at time customers requested service—kw.	9.25	4.54	3.34	6.15	5.63	5.59*
Average initial connected load at time customers were given service—kw	7.75	5.68	3.70	6.51	3.81	5.11*
Average kw. connected load per customer at time of special test period—Total	9.69	7.296	4.613	8.684	5.65	6.88*
Average kw. connected load per customer at time of special test period—Lighting	0.877	0.708	0.552	0.875	0.845	0.80*
Average kw. connected load per customer at time of special test period—Ranges	7.08	3.785	2.691	5.350	3.318	4.20*
Average kw. connected load per customer at time of special test period—Laundry equipment	0.708	0.466	0.695	0.834	0.554	0.667*
Average kw. connected load per customer at time of special test period—Pump motors	0.685	2.090	0.59	0.557	0.746	0.761*
Average kw. connected load per customer at time of special test period—Cream separator motors	0.12	0.15	0.044	..	..	0.031*
Average kw. connected load per customer at time of special test period—Miscellaneous equipment	0.22	0.097	0.041	1.068	0.172	0.421*
Average size of transformers on line—kv-a	7.5	4.5	2.6	6.6	4.5	5.24*
Average 15 min. kv-a. demand on transformers during test period	3.60	2.64	1.61	3.11	2.19	2.63
Average transformer demand factor during test period (1)	0.19	0.298	0.32	0.273	0.333	0.28
Maximum 15 min. kw. demand of line during test period	5.54	6.6	8.45	15.4	12.	9.60
Line power factor at time of maximum demand	94%	89%	97%	96%	93.8%	94%
Demand factor of line during test period (2)	0.095	0.151	0.141	0.077	0.085	0.109
Diversity factor between line and transformer demands (3)	0.514	0.654	0.57	0.344	0.342	0.48
Per cent line, transformer and meter losses (4)	19.5%	24.4%	37.4%	32.8%	28.9%	28.6%
Annual kw-hr. delivered to customers—Average per customer	1694.	826.	640.	1401.		1046*†
Month and kw-hr. of maximum use of energy—Average per customer	239 July	160 Aug.	80 Oct.	124 Sept.		121 Jul.*†
Month and kw-hr. of minimum use of energy—Average per customer	91 Mar.	32 Sept.	28 Apr.	78 Mar.		69 Mar.*†

*Weighted averages.
†New line. Kw-hr. figures not available or considered in determining weighted averages.
1. Transformer demand factors are the ratios obtained by dividing the maximum 15-min. transformer demands by the total transformer connected loads.
2. Line demand factors are the ratios obtained by dividing the maximum 15-min. line demands by the total connected loads on the line.
3. Diversity factors of line and transformers are the ratios obtained by dividing the maximum 15-min. line demand by the sum of the individual maximum 15-min. transformer demands.
4. Per cent losses are based upon the difference between measured kw-hr. line input and kw-hr. recorded on customers meters over an extended period of time.

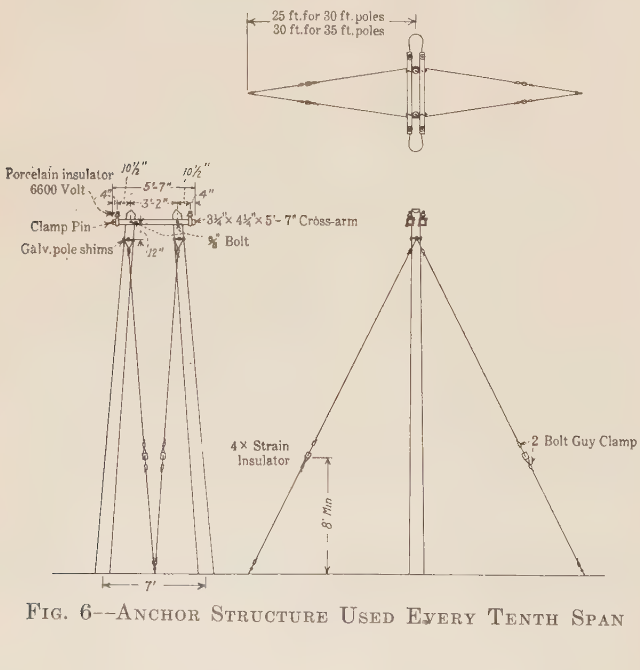

FIG. 6—ANCHOR STRUCTURE USED EVERY TENTH SPAN

These data are shown in Table II. It is interesting to observe that in general more load was found connected than the farmers agreed to connect when contracting to take the service. While the average contracted for was 5.59 kw., the average found connected was 6.88 kw.

Another fact of interest is that the transformer loading was found to be low. It is known from individual consumers' records that the maximum consumption is very apt not to occur in the winter, when these data were taken. This may be partly due to the fact that in the summer the farmer uses his electric range while in the winter he uses a wood range. He also does more pumping in the summer and carries on other operations more extensively. Comparable data taken during the summer months will show whether transformers larger than necessary have been furnished or not.

The power factor at time of maximum load was found to vary from 89 per cent to 97 per cent on the various lines tested. Annual kw-hr. per consumer on the vari-

ous lines averaged from 640 to 1694. Line, transformer, and meter losses were found to vary from 19.5 per cent to 37.4 per cent.

Fig. 8 shows the number of consumers served under the rural rate by years from 1920, when the rate was adopted, to January 1, 1926, when there were 2740 rural consumers connected.

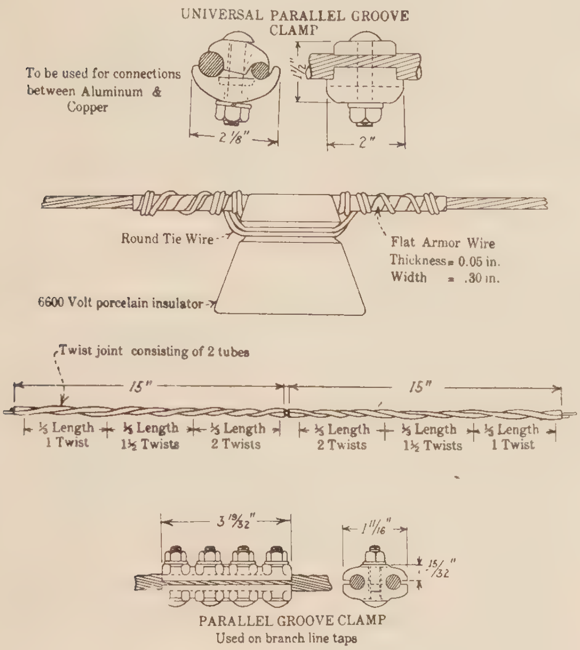

Fig. 7—Clamps, Splice and Tie

Conclusion

Utility companies must view the rural business broadmindedly and provide a reasonable line extension plan, and rate schedule which will encourage the use of the service. A rate schedule designed to pay full returns on investment from the very start, by using burdensome minimum charges or high rates per kw-hr., will produce the opposite result.

A financing arrangement has been found to be necessary, because a rural line extension project involves a number of farmers, all of whom must arrive at the buying point at one time. Where the farmers' activities are somewhat varied, all may not have the funds available at the time the project is developed to the final stage. If it cannot be concluded then but has to be postponed because some do not have the funds available, when it is reopened, some of the others may not have the funds available, and often a project is delayed for an indefinite period of perhaps a year or two. A farmer who can afford to go into such a project at all will have the funds available at sometime within a year. A plan whereby his financial obligations can be taken care of satisfactorily until such time as he has the funds available leaves no obstacle in the way of concluding the negotiations when all agree upon terms.

Experience has demonstrated that the all important thing in general rural electrification is to make the service available to the farmers. The records show that as soon as the service is available the farmers will find new and increasing ways of utilizing it as industries in the urban centers have done and are continuing to do. Every farm can be made a laboratory in a greater or lesser degree for carrying on experimental work, and the greater the number of farms carrying on such work, the greater will be the increase of new applications for the service. It is important, therefore, for utilities to cover their rural territories as quickly as possible with suitable supply lines. This can be done with reasonable assurance that load not contemplated now will develop as new uses for the service are found and as the people come to realize, as they can only through use and reasonable encouragement on the part of the utility, its many and varied advantages.

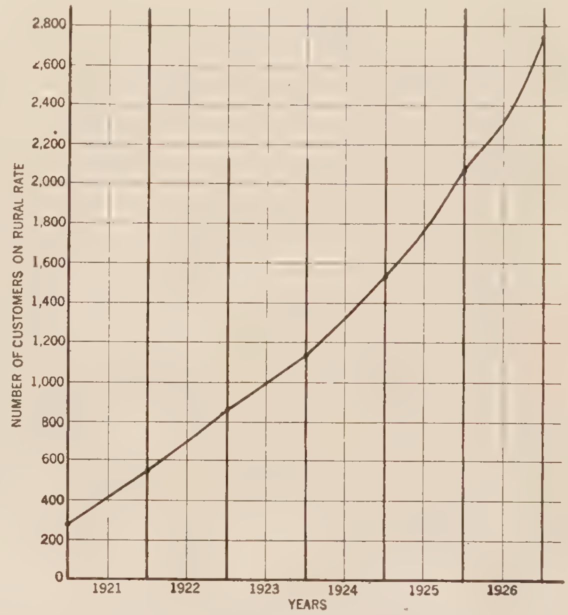

Fig. 8—Number of Rural Customers on Line of the Milwaukee Electric Railway and Light Company and Associated Companies by Years

ELECTRIC "EYE" SORTS CIGARS

A cigar sorting machine has been perfected for use by cigar manufacturers, which has proved exceptionally accurate and speedy in its work. Cigars are sorted according to the shade of their coloring into no less than thirty separate grades, and to do this successfully requires, in a human, an exceptionally well trained eye. Recently an electrically operated machine has been developed for this purpose which will do this work with greater speed and accuracy. As this device automatically picks up each cigar and holds it up to its "eye," a photoelectric cell, the various shades of brown cause varying reactions in the photoelectric cell, and relays actuated by these different currents select the compartment in which the cigar belongs. The machine grades sixty cigars every minute.

A Contribution to Research on the Experimental Determination of the Losses in Alternators

BY EDOUARD ROTH[1]

Associate, A. I. E. E.

Synopsis.—*In this paper the author deals with one of the questions with which the International Electrotechnical Commission is at present occupied; namely, the determination by simple tests of the actual losses in alternators. The author first reviews the existing rules and then states the variation of the losses in alternators as a function of the load and as a function of the power factor. His paper contains records of experimental researches which he has made and which serve on the one hand as a basis for discussion of the theoretical considerations which he develops and on the other hand to compare the actual losses with those obtained by the methods given in the rules at present in force. The author does not present definite conclusions since, in his opinion, these investigations ought to form the basis for a program of future researches and ought to serve as the basis for discussions in the Rating Committee of the International Electrotechnical Commission.*

* * * * *

INTRODUCTION

THE separate loss method is still often considered as sufficient for the experimental determination of the efficiency of electric machines. In this method a no-load test at the normal voltage gives the mechanical losses, friction and windage losses, as well as the core or magnetic losses. The electrical losses due to the current in the armature and the excitation circuit are calculated on the basis of the resistances, when hot, of the various circuits and the currents in these circuits. This method gives, of course, good results in the case of small machines and it is not desired to supersede it, but in the case of large machines, and especially in large alternators it gives absolutely incorrect results. In fact, this method does not take into account either the actual electrical losses, or the fact that the iron losses correspond to an internal voltage higher than that at the terminals, and it totally excludes the phenomena by which the no-load conditions differ from the conditions under load. In short, it neglects the stray load-losses.

Therefore, the modern tendency is to investigate methods by which, with simple tests, the actual losses in the machines may be determined with great accuracy when carrying full load.

The American Institute of Electrical Engineers was the first of the electrical associations in any of the various countries to establish elaborate rules on this subject.

In what follows the excitation loss will not be taken into consideration since this can be determined with sufficient accuracy by simple tests. In fact, rules established by these associations give methods which make it possible to calculate the exciting current on load from the no-load and the short-circuit characteristics. Besides, it is always possible to get the exact value of the excitation loss by a test on load. It is much more difficult to determine the magnetic loss and particularly the electric loss in the armature.

1. Engineer-in-Chief, Société Alsacienne de Constructions, Mécaniques, Belfort, France.

Presented at the Midwinter Convention of the A. I. E. E., New York, N. Y., February 8-11, 1926.

With regard to core loss, the Standards of the A. I. E. E. (1925 revision) read as follows:

"7-468 Core losses.—Drive the machine from an independent motor, the output of which shall be suitably determined. The brushes shall be in contact, and the machine shall be excited, so as to produce at the terminals a voltage corresponding to the calculated internal voltage for the load under consideration. The difference between the output obtained by this test and that obtained by test under paragraph 7-467 shall be taken as the core loss.

The internal voltage of synchronous machines shall be determined by correcting the terminal voltage for the resistance drop only."

To determine the losses on load, these Standards propose to augment the core losses by the stray load-losses. In regard to the stray load-losses they read as follows:

"7-470 Stray Load Losses.—These include iron losses, and eddy-current losses in the copper, due to fluxes varying with load and also to saturation.

Stray load-losses shall be determined by operating the machine on short-circuit and at rated-load current. This, after deducting the windage and friction and $I^2 R$ loss, gives the stray load-loss for polyphase generators and motors."

This method of obtaining the stray load-losses from the short-circuit tests has likewise been adopted in France. However, the following method may also be used alternatively:

"With the rotor removed and the stator winding carrying normal current at rated frequency, the power input is measured.

This value, after deduction of the $I^2 R$ losses, represents the supplementary losses."

Several comments will be made on these rules: First, it is easy to see that the geometrical addition of the ohmic drop to the normal voltage has no influence whatever on the value of the iron loss to be introduced in the calculation of the efficiency. However, this rule shows that a certain correction should be made to the normal voltage to account for the actual core loss on

load. One of the main objects of this study is to determine the precise amount of this correction.

Then, with regard to losses other than the core loss, that shall be accounted for on load, two questions should be answered; first, do the two tests give the same result and second, in what proportion is this result to the actual losses.

It is well known that in turbo alternators or in general, in high armature reaction alternators, the *short-circuit losses* measured are very much too high; the tests reported hereafter were made to determine whether or not this is the case with salient pole alternators of small size and small armature reaction. It is essential to know the value of the armature reaction in determining the accuracy of the short-circuit test as a method of measuring the stray load-loss. Several authors[2] have already given reasons for this experimental feature in the case of turbo alternators, and it is needless to go into them here. However, these reasons cannot be applied to salient pole alternators; but contrary to what is generally admitted, it seems that the iron loss on short circuit cannot be neglected

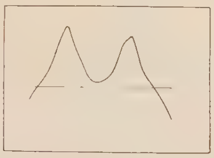

FIG. 1—FIELD CURVE ON SHORT-CIRCUIT

on account of the well-known shape of the field curve. See Fig. 1 as an example of such curves.

On the contrary, the results of the test with *rotor removed* seem to be nearer actual conditions, even in the turbo alternators. One objection to this test is that it is carried out with a very low power factor which implies a lack of accuracy in the readings of the wattmeters, especially if current transformers are used.

Reviewing the situation it may be stated that the core loss determined according to the A. I. E. E. Standards is certainly too small, while the electrical losses resulting from the short-circuit test are often too large. However, it may be possible, as already expressed at the Hague, that the sum of these two indications is sufficiently close to the actual value of the losses on load. In the event that this could be proved for a sufficient number of very different machines, the prescribed rules of the Standards would hold good.

We trust that the tests reported hereafter will shed some light on these various questions. These tests have been carried out at the works of the Société Alsacienne de Constructions Mécaniques, at Belfort. These measurements are very delicate, and in order that definite conclusions be reached other manufacturers should make similar tests. We consider the present study more as a basis for discussion and as a program for further investigations.

Definitions. As in the plain separate loss test the losses will still be segregated into mechanical, magnetic and electric. No special comment is necessary with regard to the first; these include the sum P_0 of the friction losses in the bearings, the friction losses of the brushes, etc., as well as the windage and the ventilation losses. By *magnetic* losses is meant those due to flux. These are developed principally in the active iron, however, they can develop elsewhere. They include, for example, the losses at the surface of the pole pieces, those in the fastening bolts and in the end-bells or end-plates, where they are generated by the leakage flux of the inductor. They vary with the load and are in consequence a function of both the current I and the voltage U. By *electric* losses are meant the losses proportional to the square of the current. They appear not only in the copper of the armature but in every part of the machine where currents are induced by the main current, such as end-bells, end-plates, dampers, etc.

Neglecting, as stated above, the excitation loss in the machine, the total losses, P, can be represented by the following equation:

$$P = P_0 + f\,(U, I) + a\,I^2 \qquad (1)$$

The above definitions do not mention the stray load losses as these are included either in the magnetic or electric losses.

Electric losses. The coefficient a in the expression $a\,I^2$ is equal to the resistance r of the winding, multiplied by a factor k greater than unity.

$$a = k\,r$$

It should be noted here that the electric losses are not necessarily proportional to the square of the current. When the solid parts subjected to the induced currents become saturated by flux, it may happen that some of these terms vary according to another law. But, as stated above, we will neglect such variation and assume the law of the square.

In what follows we will assume that for a given temperature of the machine and consequently for a well determined value, r, of the resistance, the value of k is independent of the value of the current and of its phase angle.

Variation of the magnetic loss with the load. Curve I of Fig. 2 represents the no-load losses of an alternator running as a synchronous motor at no-load, with minimum current. This curve we shall call the "no-load loss characteristic." It is desired to find on this curve the value of the virtual internal voltage corresponding

2. S. F. Barclay, "The Mechanical Design and Specification of the Turbo Alternator Rotor." *Jour.* I. E. E., 1919, p. 483.

E. Roth, "Les pertes supplémentaires dans les machines électriques." *Bulletin de la Société Francaise des Electriciens,* 1923, p. 497.

E. Roth, Les alternateurs de 40,000-kw. construits par la Société Alsacienne de Constructions Mécaniques pour la Centrale de Gennevilliers de l'Union d'Electricité. *Revue Générale de l'Electricité*, 24 Février 1922, XIII, p. 311.

to the magnetic loss on load, for a given current and a given phase angle, which voltage we will call the "magnetic loss voltage."

Let $O\,A$ (Fig. 3) represent the normal voltage U_0 at the terminals, or else the flux in the machines; add geometrically to $O\,A$ the ohmic drop $A\,B = k\,r\,I$, also the inductive drop $D\,B = x\,I$, due to the leakage flux, to obtain the total electromotive force $O\,D$ (or $O\,D'$ in the case of a leading angle of phase when running as a generator).

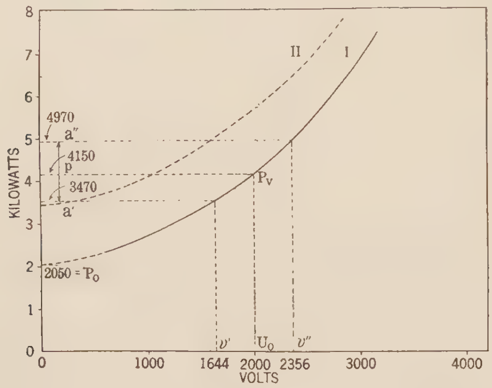

Fig. 2—Characteristics of Core Losses

It would be very simple, as it has been proposed, to adopt for the value of the magnetic loss voltage that corresponding to the vector $O\,D$, as the inductive drop $B\,D$ due to leakage can be measured with sufficient accuracy without difficulty.[3]

This method has already been proposed at the Hague and it may be possible that the results of the studies now in progress will lead to its insertion in the rules.

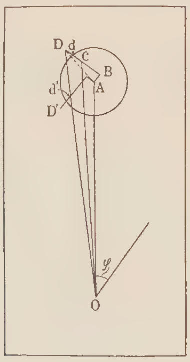

Fig. 3

However, there are several reasons why the voltage $O\,D$ does not represent the magnetic loss voltage.

First, the inductive drop $B\,D$ due to the leakage is composed of two parts: the one $B\,C$ corresponding to the leakage in the end turns of the coils, the other $C\,D$, due to the leakage in the slots. But the flux in the core is only $O\,C$, so that taking the voltage $O\,D$ as the magnetic loss voltage will, therefore, give too high values.

Further, the leakage flux in the slots tends to saturate the teeth which separate the slots belonging to two different phases when the alternator runs on a capacitive load, and tends to weaken the flux in the teeth when it runs on an inductive load, which increases the losses in the first case and reduces them in the second.[4]

Obviously, it may be inferred that it would not be correct to add vectorially the total inductive drop $B\,D$ to obtain the magnetic loss voltage; it seems that a virtual inductive drop $x_p\,I = D\,d$ should be added, (less than $B\,D$), to obtain this voltage. Running with a lagging phase angle, the losses would be smaller than those corresponding to the inductive drop $O\,D$; while with a leading angle of phase they would be higher since $O\,d'$ is greater, in that case, than $O\,D'$.

But a very important experimental fact invalidates these conclusions in great proportion. It is known that the field curve along the surface of the poles of salient-pole alternators varies considerably with the phase angle of the current.

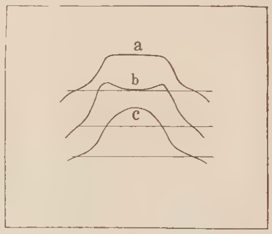

Fig. 4—Field Curves of Alternator
a. No load b. Lagging c. Leading

This curve inflects with lagging armature current (field over-excited) and swells, becoming nearly a sine wave with leading current (field under-excited).

Fig. 4 is an example of such curves. Fig. 4A represents a field curve at no-load and Figs. 4B and 4C correspond to lagging and leading phase angles respectively. But the curves of the type of Fig. 4B give higher losses than those of the shape of Fig. 4C; this is proved theoretically and confirmed by tests. Thus the points d and d' draw nearer again to D and D^1. See Fig. 3. It is proposed to precisely determine, by suitable tests, whether, and by how much, the virtual inductive drop $B\,d = x_p\,I$, which we call the "inductive drop of loss" differs from the inductive drop of leakage $B\,D$.

Owing to the secondary phenomena we have just mentioned there is nothing to indicate that the reactance of loss, x_p, is independent of the phase angle for a given current. However, in the following developments we will assume that the reactance x_p is constant. On this assumption, the current being constant, when the phase angle varies, the point d describes a circle around A

3. E. Roth, "Critique de quelques méthodes de mesure de la resistance due aux fuites de l'induit des machines électriques rotatives a courants alternatifs." *Revue Générale de l'Electricité* du 7 Juin 1925, XVII, p. 217.

4. E. Roth, "Les pertes supplementaires dans les machines electriques," *Bulletin de la Société Francaise des Electriciens*, 1925, p. 495.

as a center, with $A\,d$ as a radius. This assumption as well as that of the constancy of the factor k shall be justified by tests.

Determination of the constants k and x_p from measurements of the losses, the machine being run as a synchronous motor at no-load, with variable current:[5] It is possible to run an alternator approximating normal conditions at no load as a synchronous motor, either over-excited or under-excited at nearly zero power factor, the current being the same in each case. The power input in these two tests represents the losses, and will not only give the reactance of loss x_p and consequently the magnetic loss, but also the electric losses and, therefore, the factor k.

The conclusions that can be drawn from these tests amply justify the assumptions, for these are the limiting values of the secondary phenomena and particularly of the variation of the shape of the field curve.

In fact, for the over-excited conditions, the total losses P'' may be expressed for a three-phase alternator by

$$P'' = P_0 + 3\,k\,r\,I^2 + f\,(U'') \qquad (2)$$

r being the resistance per phase. U'' is the loss voltage corresponding to these running conditions (Fig. 2) and as shown in Fig. 5 is approximately:

$$U'' = O\,N'' = U_0 + x_p\,I\,\sqrt{3} \qquad (3)$$

x_p being the reactance of loss per phase.

Similarly, in the under-excited conditions:

$$P' = P_0 + 3\,k\,r\,I^2 + f\,(U') \qquad (4)$$

where

$$U' = O\,N' = U_0 - x_p\,I\,\sqrt{3} \qquad (3\,\text{a})$$

Subtracting (4) from (2)

$$\begin{aligned} p &= P'' - P' = f\,(U'') - f\,(U') \qquad (5) \\ &= a'' - a' \text{ taken on Fig. 2.} \end{aligned}$$

The question is then to obtain by successive approximations, which are easily made, two values of U' and U'', symmetrical with regard to U_0, and such that the difference of the losses measured on the loss characteristic (Fig. 2) is equal to p.

Then:

$$x_p = \frac{U'' - U_0}{I\,\sqrt{3}} = \frac{U_0 - U'}{I\,\sqrt{3}} \qquad (6)$$

Substituting this value of x_p in equation (3) gives U'', and this, when substituted in equation (2) determines $K\,r$. Now, since r is known, K is obtained.

Knowing the values of k and x_p, the loss at any load may be calculated. The magnetic loss voltage $O\,M$ for any running condition may be determined from the diagram of Fig. 5; and knowing this, the magnetic losses may be obtained from the loss curve, to which the $k\,r\,I^2$ losses are to be added and also the mechanical losses P_0.

5. In other words, readings of the power input are taken when the alternator is run as a synchronous motor for the V-curve test.

It is to be noted that this method, as in the case with the rotor removed, involves the disadvantage of being carried out at a low power factor. However, with certain precautions, this method can be carried out successfully, as the following tests indicate. If wattmeters gave correct readings at low power factor, this method could be extended to the calculation of the losses in any running condition, provided, of course, that the above assumptions be justified by tests.

Study of the curve of the losses as a function of current when running as a synchronous motor at no-load. The above assumptions could first be checked in the following manner: Simultaneously with the readings for the V curve, readings of the corresponding losses are taken, and then a curve of these losses is drawn in terms of the current. We have called this a comet curve because of its special shape. Readings of the losses are then taken for the same current I_1 on the two branches of the curve, corresponding to which, values of x_p and k are deducted according to the above method and from these values the comet curve is plotted. The

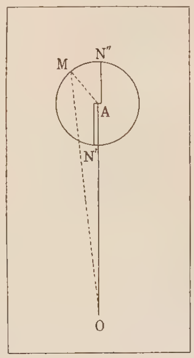

FIG. 5

coincidence of the calculated curve and that obtained from test will justify the assumptions.

This calculation is possible only when the equation of the no-load-loss characteristic is known. It is particularly simple in non-saturated machines where this curve is a quadratic parabola.

In this case it is possible to avoid the cut-and-try method by solving equation (5); $f\,(U)$ is then of the form, $\dfrac{U^2}{\rho}$. The analytical solution is given by the equation:

$$p = \frac{U''^2}{\rho} - \frac{U'^2}{\rho} \qquad (7)$$

since:

$$(U''^2 - U'^2) = (U'' - U')\,(U'' + U')$$

$$U' + U'' = 2\,U_0 \qquad (8a)$$

$$U'' - U' = 2\,x_p\,I_1\,\sqrt{3} \qquad (8b)$$

Thence:

$$p = \frac{(U'' + U')\,(U'' - U')}{\rho} = \frac{4\,U_0\,x_p\,I_1\,\sqrt{3}}{\rho}$$

which gives:

$$x_p = \frac{p\,\rho}{4\,U_0\,I_1\sqrt{3}} \tag{9}$$

ρ can then be determined by setting up the following expression for the losses corresponding to the voltage U_0—see Fig. 2.

$$\frac{U_0^2}{\rho} = P_v - P_0 \text{ and } \rho = \frac{U_0^2}{P_v - P_0}$$

k is then deducted and thus it is possible to calculate the electric losses and to plot the comet curve for the various values of the current.

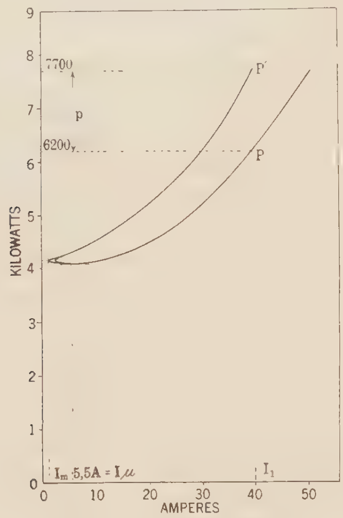

Fig. 6—Comet Curve

Were it possible to assume the no-load loss characteristic to be a parabola of the second order, the above mentioned method could be employed to give a first approximation of the value of x_p, later to be revised by a cut-and-try process.

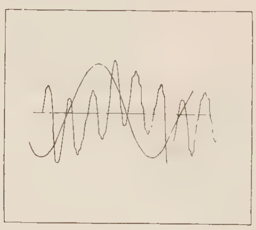

Fig. 7

Formulas (**8a**) and (**8b**), and the conclusions drawn therefrom, have been based on the assumption of zero power factor. This condition is fulfilled even for small values of current, and it is only for currents near the minimum of the V curve that the method indicated fails.

If it is assumed that the no-load-loss curve is a quadratic parabola, it is possible to calculate the comet curve for the exact value of the angle of phase; however, to give this study a practical instead of a theoretical aspect, we will not present this development here. The curve of Fig. 6 has thus been calculated, and for the current I, the corresponding losses are P'' and P'.

Even when variable power factor is taken into account near minimum current, the points of the comet curve do not correspond with those of the curve obtained from the tests. It is known that the wave form of minimum current of a synchronous motor is very distorted (Fig. 7). The minimum current read will be higher than that corresponding to the voltage and the power. This explains why the test results give the dotted part of the comet curve shown in Fig. 6.

The comet curve has a peculiar characteristic which may appear paradoxical at first. This feature is of no practical interest. However, it may confirm our hypothesis. It will be noticed on Fig. 6 that the minimum loss does not correspond to the minimum current. The losses decrease in a certain part of the curve when the current increases. This minimum loss occurs when the conditions are such that the increase of the electrical losses $k\,r\,I^2$ is less important than the corresponding decrease of the magnetic loss. Hence, this minimum occurs for a certain ratio between x_p and $k\,r$.

The existence of this minimum is easily explained analytically in the simple case of the quadratic parabola. Since this minimum can only occur in under-excited conditions, formula (**4**) reads as follows:

$$P' = P_0 + k\,r\,I^2 + \frac{(U_0 - x_p\,I\sqrt{3})^2}{\rho}$$

which gives:

$$p' = \left(P_0 + \frac{U_0^2}{\rho}\right) - \frac{2\,x_p\,U_0\sqrt{3}}{\rho}\,I + 3\left(\frac{x_p^2}{\rho} + k\,r\right) I^2$$

as the equation of the lower branch of the comet curve, on the assumption of zero power factor, which as stated, is permissible, even for small values of current.

This parabola gives a minimum corresponding to a current:

$$I_u = \frac{U_0}{\sqrt{3}}\,\frac{x_p}{(x_p^2 + k\,r\,\rho)} \tag{12}$$

and a power:

$$P_u = \left(P_0 + \frac{U_0^2}{\rho}\right) - \left\{\frac{U_0^2}{\rho}\right\}\left\{\frac{x_p}{x_p^2 + k\,r\,\rho}\right\} \tag{13}$$

$$P_u = \left(P_0 + \frac{U_0^2}{\rho}\right) - \frac{x_p}{\rho}\,U_0\,I_u\sqrt{3}$$

which, remembering that the term $P_0 + \dfrac{U_0^2}{\rho}$ represents the no-load loss P_v at the pressure U_0, therefore, can be written

$$P_u = P_v - \frac{x_p}{\rho}\,U_0\,I_u\sqrt{3} \tag{13a}$$

This minimum power has no physical existence unless the value of the minimum current I_m taken by the

motor be less than the current I_u corresponding to the minimum of the losses

$$I_m < I_u \tag{14}$$

It can be shown that this corresponds to the condition

$$\frac{P_v}{P_v - P_0} k\, r < x_p \tag{15}$$

or

$$\frac{\text{Total no-load losses}}{\text{No-load core losses}} k\, r < x_p$$

Experimental researches. A series of tests have been carried out on a 320 kv-a. 3000-volt, 61.6-ampere, 50-cycle, 26-pole synchronous motor. The results of these tests have been translated into the curves of Figs. 1, 2, 4, 6 and 8. The comet curve of Fig. 6 and the field curve of Fig. 4 have not been obtained at the normal voltage of 3000 but at 2000 volts, as the no-load loss characteristic at the latter voltage very nearly follows the law of the square, and also because the differences in the field curves are more pronounced when the alternator is not saturated.

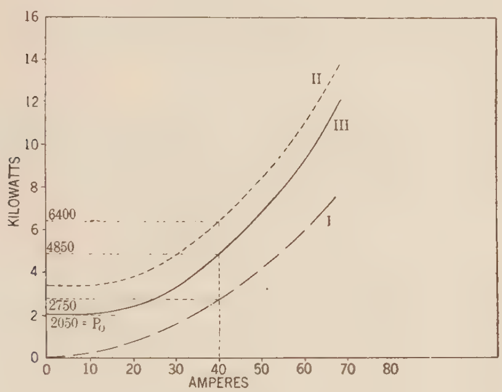

Fig. 8—Characteristics of Electrical Losses

I—Losses, measured, rotor removed

II—Short circuit losses

As already explained, this characteristic has been obtained from the value of the power input with the machine running as a synchronous motor, at no-load and at the minimum current. The motor became unstable below 620 volts. Therefore, the dotted part of the curve had to be assumed in order to determine the mechanical losses; $P_0 = 2050$ watts. The total losses P_v on no-load at $U_0 = 2000$ volts are 4150 watts, which gives as the iron loss $4150 - 2050 = 2100$ watts.

ρ will be obtained from

$$2100 = \frac{2000^2}{\rho}$$

thence, $\rho = 1905$ ohms.

The iron losses at 2356 volts and 1644 volts are:

$4970 - 2050 = 2920$ watts and

$3470 - 2050 = 1420$ watts, respectively.

In order to determine whether the law of the square is satisfied, at 2356 volts we find

$$\frac{2356^2}{1905} = 2905 \text{ watts against } 2920 \text{ watts;}$$

and at 1644 volts

$$\frac{1644^2}{1905} = 1418 \text{ watts against } 1420 \text{ watts}$$

These results are practically identical. At 3000 volts, on the contrary, the curve considerably deviates from the quadratic parabola.

Let us now refer to the comet curve of Fig. 6. With the alternator running at no load as an over-excited synchronous motor, and carrying an armature current of 40 amperes, the power input was 7700 watts as compared with 6200 watts for the under-excited conditions.

Then $p = P'' - P' = 7700 - 6200 = 1500$ watts

Formula 9 gives for the reactance of loss,

$$x_p = \frac{p\, \rho}{4\, U_0\, I_1 \sqrt{3}} = \frac{1500 \times 1905}{4 \times 2000 \times 40 \sqrt{3}} = 5.14 \text{ ohms.}$$

and for the inductive drop of loss,

$$x_p I_1 \sqrt{3} = 5.14 \times 40 \sqrt{3} = 356 \text{ volts}$$

The loss voltages are respectively:

$$U'' = U_0 + x_p\, I_1 \sqrt{3} = 2000 + 356 = 2356 \text{ volts}$$

$$U' = U_0 - x_p\, I_1 \sqrt{3} = 2000 - 356 = 1644 \text{ volts}$$

Equation (**2**)

$P'' = P_0 + f\,(U'') + 3\, k\, r\, I^2$ becomes

$$7700 = 4970 + 3\, k\, r\, I^2$$

Whence $3\, k\, r\, I^2 = 2730$ watts.

The resistance r per phase is

$$r = 0.52 \text{ ohms}$$

which gives

$$k = \frac{2730}{3 \times 0.52 \times 40^2} = 1.094$$

or $k\, r = 0.569$ ohms

Thus, we know all the data required for the calculation of the comet curve. This has been traced on Fig. 6 and practically coincides with the curve obtained from the tests. The coincidence is particularly marked for the minimum P_u of the losses. The existence of this minimum is evidenced by the verification of the following inequality:

$$\frac{\text{Total no-load losses}}{\text{No-load iron losses}} k\, r < x_p$$

which gives in our case;

$$\frac{4150}{2100} \times 0.569 < 5.14$$
$$1.13 < 5.14$$

The corresponding current I_u for minimum input is, according to (**12**)

$$I_u = \frac{U_0}{\sqrt{3}} \times \frac{x_p}{x_p^2 + k\,r\,\rho} = \frac{2000}{\sqrt{3}} \times \frac{5.14}{5.14^2 + 0.569 \times 1905}$$

$I_u = 5.35$ amperes.

The minimum power P_u is, according to (**13a**)

$$P_u = P_v - \frac{x_p}{\rho}\, U_0 I \sqrt{3}$$

$$P_u = 4150 - \frac{5.14}{1905}\, 2000 \times 5.35 \sqrt{3}$$

$$P_u = 4100 \text{ watts}$$

this being 50 watts less than the total no-load losses.

The minimum current I_m measured was 2.1 amperes. This high value results from the distortion of the current wave (Fig. 7). If the current wave were a sine, the actual current should be:

$$\frac{4150}{2000\sqrt{3}} = 1.2 \text{ amperes}$$

The problem is now to determine, first the ratio of the reactance of loss x_p to the leakage reactance x and then the ratio of the actual losses to the losses given, either by the test with rotor removed or by the short-circuit test.

The ratio of reactances was obtained by a method proposed by the writer[6]. The rotor being removed, a rectangular coil was arranged on the stator core, two sides being parallel with the axis of the machines and the two other sides running along the ends of the core. This coil embraced one pole pitch and consisted of one or more wires.

The stator winding was then supplied with a current I_s of frequency f and readings were taken of the impressed voltage U_s, and also of the voltage u_s across the ends of the rectangular coil.

Let v be the number of turns of the coil, r_s and r_v respectively the resistances of the coil and the voltmeter across the terminals of the coil. The flux across the cylindrical space inside the stator is:

$$\Phi_e = \frac{u_s \times 10^8}{4.44\, f\, v} \left(1 + \frac{r_s}{r_v}\right) \text{ Maxwell's} \qquad (16)$$

corresponding to a pressure at the terminals of a three-phase machine of

$$U_e = 2.13 \sqrt{3}\, f\, N\, \Phi_e\, 10^{-8} \text{ volts} \qquad (17)$$

N being the number of conductors in series per phase.

The reactance x due to the leakage of the stator is then:

$$x = \frac{U_s - U_e}{I_s \sqrt{3}} \qquad (18)$$

For a current $I_s = 67$ amperes, the following voltages have been obtained,

$$U_s = 861 \text{ volts}, \quad u_s = 0.441 \text{ volts}$$

at $f = 50$ cycles per second.

The coil was made up of but one wire making $v = 1$; r_s and r_v were

$$r_v = 4.7 \text{ ohms}, \; r_s = 0.17 \text{ ohms}$$

corresponding to

$$\frac{r_s}{r_v} = 0.036$$

Hence,

$$\Phi_e = \frac{0.441 \times 1.036 \times 10^8}{4.44 \times 50} = 0.207 \times 10^6$$

and for $N = 728$ conductors per phase,

$U_e = 2.13 \sqrt{3} \times 50 \times 728 \times 0.207 \times 10^{-2} = 278$ volts

Therefore,

$$x = \frac{861 - 278}{67\sqrt{3}} = 5.02 \text{ ohms}$$

which corresponds nearly to the value of 5.14 ohms found for x_p.

In this case it is permissible to take as the value of the inductive drop of leakage of the stator that of the inductive drop of loss.

While the above test was made at a variable current, readings of the stator losses were taken, (Curve *I*, Fig. 8) giving, for 40 amperes, a loss of 2750 watts, which is practically equal to the above loss,

$$3\, k\, r\, I^2 = 2730 \text{ watts}$$

The losses on short circuit were measured as follows: The machine was driven by a direct-current motor the power input of which was measured with the alternator running on short circuit. Curve *II*, Fig. 8, gives the input to this motor in terms of the current in the alternator.

For the calibration of the motor the alternator was run on no-load, at a variable voltage, the input to the d-c. motor also being measured. Curve *II*, Fig. 2, has thus been obtained. As Curve *I* on the same figure represents the actual power input to the machine under test, it is possible to obtain the exact losses of the direct-current motor. These are measured by the difference of the ordinates of the two curves.

It is thus possible to determine the curve of the short-circuit losses of the machine as shown by (Curve *III*, Fig. 8). For a current of 40 amperes, the total losses on short-circuit are 4850 watts, of which $P_0 =$ 2050 watts, should be subtracted leaving

$$4850 - 2050 = 2800 \text{ watts}$$

This does not differ greatly from the 2730 watts found above for $3\, k\, r\, I^2$.

Therefore, according to the prescribed rules, the no-load loss P_v, at the normal pressure U_0, should be added to the losses on short-circuit. This gives a total value of

$$4150 + 2800 = 6950 \text{ watts}$$

6. Edouard Roth, *Revue Générale de l'Electricité*, 7 February, XVII, p. 217.

as compared with the values 6200 and 6700 watts obtained when the machine is run at the same current as a synchronous motor, either over- or under-excited.

It should be noted that the method of the comet curve, the method with rotor removed and the short-circuit test give the same result for the electric losses. Further, we have seen that the inductive drop of leakage represents the voltage drop of loss.

NOTE. The tests which have been carried out are relatively simple, as they only involve running the machine at no load. The conditions under which they were made do not enable us to determine the losses that may exist on load at power factors other than zero. Presently another series of tests will be carried out that will enable us to determine the value of these losses for full load and to compare them with those found by the separate loss method.

As already mentioned in this article, it is desirable that other manufacturers make similar tests before definite conclusions are established.

THE FORCE BETWEEN MOVING CHARGES*

BY V. BUSH

The classic theory of circuits, as used by electrical engineers, is founded on the assumption that charge is invariant. The new forces which come into play when charges move, that is, when current flows, are expressed in terms of magnetic fields. According to this view the force between a pair of relatively moving charges is made up of two components, one along the line joining them which is always given by Coulomb's law, and a second perpendicular to this, depending upon the velocity, and expressed by means of magnetic fields. This classic concept involves necessarily a change of mass with velocity in order to account for observed results with high-speed electrons. Such a change of mass is also given by the theory of relativity.

There is an alternative theory of circuits, originally advanced by such men as Gauss and Weber, in which there is only one component of force, and in which the concept of the magnetic field is absent. It is entirely adequate to explain all the experimental results which have been obtained with complete electric circuits. For many years it has been practically abandoned, largely on account of the work of Maxwell. The present paper develops this alternative theory and applies it to the behavior of individual electrons in the belief that the alternative theory also deserves careful attention at this time.

In this alternative scheme mass is a constant, and charge is variant. The various circuit effects, such as the force between wires carrying current and induced voltages, are accounted for on this basis by reason of this variation of charge and without the agency of magnetic fields. Some of the possible objections to the idea are then treated.

When applied to relations inside the atom this alternative method of approach gives results similar to those given by restricted relativity and variant mass. The advance of the perihelion of an electron revolving about a positive nucleus coincides with that obtained by Sommerfeld by the use of Einstein's relativity, and applied to the fine structure of the hydrogen spectrum.

According to this present scheme, there is a critical radius in the free motion of an electron about a positive charge, and this appears significant in connection with our knowledge of the atomic nucleus.

*Abstracted from *Journ. Math. & Phys.* Massachusetts Institute of Technology, Vol. V, No. 3, March 1926.

CORRESPONDENCE

HIGHWAY LIGHTING

Editor, A. I. E. E., Journal:

The communication on page 354 of the April JOURNAL brings up again the old suggestion of street surface lighting by means of a sheet of light distributed from a source in such a way as to confine it below eye level. This suggestion has no doubt been considered by nearly every engineering specialist on street lighting and presents some very interesting features.

I was especially interested in it a number of years ago but found no opportunity for trying it out until 1917, when the Kensico Dam roadway offered an ideal situation. Mr. H. A. Tinson and Mr. C. A. B. Halvorson working with the engineers of the New York Board of Water Supply, produced an installation which was admirably suitable for those particular conditions.

The study of the problem, however, seemed to indicate rather definitely that such an arrangement would not be economically practical for ordinary highways.

Some of the objections to the low mounted units for general conditions are:

1. Relatively short spacing and therefore numerous lighting units are required.

2. The accurate light-controling equipment is high in first cost and relatively inefficient.

3. Glint effect and silhouetting, which are important in highway lighting, are more or less lost, so that the lighting is less effective for vision than the amount of light on the surface would indicate.

This method of lighting, therefore, does not seem particularly promising under present conditions.

The Kensico Dam installation is described in a paper by C. A. B. Halvorson and A. B. Oday, see *Transactions,* Illuminating Engineering Society, April 3, 1920, page 153, or *Electrical World,* February 14, 1920, page 371.

G. H. STICKNEY

Harrison, N. J.

A Method for Determining the Sign of the Smaller Wattmeter Reading in Balanced Three-Phase Power Measurements

By H. K. HUMPHREY[1]

Member, A. I. E. E.

WHEN three-phase (three-wire) power is measured by the two-wattmeter method, the smaller reading may be either positive or negative, so that the total power, which is the sum of the two wattmeter readings, may be obtained by adding the smaller reading to the larger in one case, and by subtracting it in another case. On balanced load this reading is positive, and must be added, when the power factor is greater than 50 per cent; it is negative and must be subtracted when the power factor is lower than 50 per cent. However, unless the power factor is known, it is necessary to make sure by some other means which is the correct sign for this smaller reading; failure to do so has sometimes led to curious if not serious error. For balanced load, there are in use several methods of determining the sign of this reading at the time of test. These require that either the connections or the load be altered and that additional data be taken. Often enough, however, this sign is questioned only after the test is completed and the apparatus scattered, and in this case it is apparent that a determination which depends upon a simple consideration of the usual instrument readings would be useful. Such a method is the one to be described. It is applicable only to balanced three-phase loads and sinusoidal wave forms, but in itself gives an indication of the extent to which results are affected by variation from these conditions.

The belief seems to be general that for any set of readings of line voltage, E_L, line current, I_L, and the two wattmeter readings, W_1 (larger) and W_2 (smaller), there are two possible conditions of power factor, one greater than 50 per cent in which W_2 is positive, and one lower than 50 per cent in which W_2 is negative. That is, for instance, if E_L is 200 volts, I_L, 31.1 amperes, W_1, 5.60 kw., and W_2 + 0.34 kw. (power factor 55 per cent), there would be expected for some lower power factor the readings; E_L; 200 volts, I_L, 31.1 amperes, W_1, 5.60 kw., W_2 – 0.34 kw. This is not the fact, however; there is no such possible set of readings on a balanced system with sine-wave voltage and current. The condition of load which would give a reading W_2 of – 0.34, with the same values of voltage and current would give a reading W_1 of 5.23 kw., not 5.60; or, for the same voltage, the load which would give 5.60 kw. for W_1 and – 0.34 kw. for W_2 would require 33.3 amperes, not 31.1. The accompanying curve, which shows each wattmeter reading, W_1 and W_2, separately for all values of power factor ($E_L I_L$ = 1.0), will make this fact clear. The curves are obtained by plotting against cos ϕ the ratios $\frac{W_1}{E_L I_L}$ and $\frac{W_2}{E_L I_L}$ calculated from $W_1 = E_L I_L \cos(\phi - 30 \text{ deg.})$ and $W_2 = E_L I_L \cos(\phi + 30 \text{ deg.})$[2]

Stated in a somewhat different form, any particular pair of wattmeter readings (sign considered, of course) can be obtained for only one value of the product $E_L I_L$ or of volt-amperes ($v\sqrt{3}\, E_L I_L$); this value is not the same for positive W_2 as for negative, which may be shown as follows

The power is, of course, $W_1 + W_2$; the wattless volt-

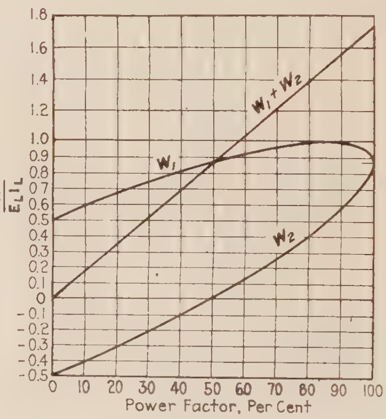

FIG. 1

amperes are $v\sqrt{3}(W_1 - W_2)$[3]. From these, the volt-amperes, $V A$, can be computed:

$$V A^2 = (\text{watts})^2 + (\text{wattless volt-amperes})^2$$
$$= (W_1 + W_2)^2 + 3\,(W_1 - W_2)^2$$
$$= 4\,(W_1^2 + W_2^2 - W_1 W_2) \qquad (1)$$

Equation (1) shows that the volt-amperes are always larger if W_2 is negative. But the volt-amperes can also be computed from

$$V A = v\sqrt{3}\, E_L I_L \text{ or } V A^2 = 3\, E_L^2 I_L^2 \qquad (2)$$

The values of $V A$ (or of $V A^2$), computed from the data by (1) and by (2), will not check if the wrong sign has been used for W_2; but if the proper sign has been used, and if there is no disturbing factor such as unbalance, they will agree; failure to check for both assumptions as to sign of W_2 signifies an error in either test or computation, unbalanced load, or harmonics in voltage or current, and the degree of disagreement may be taken as a measure of the effect of these disturbing conditions.

1. Assistant Professor of Electrical Engineering, The Rice Institute, Houston, Texas.

2. See R. R. Lawrence, Principles of Alternating Currents, p. 331.

3. R. R. Lawrence, op. cit., p. 334.

One method of checking, then, is to compute the volt-amperes not only from the voltmeter and ammeter readings (**2**), but also from the wattmeter readings; (**1**), equation (**1**) should be used twice, once taking W_2 positive, the other time negative; unless disturbed by faulty readings, unbalance, or distorted wave-forms, one of the values computed from (**1**) will check the value obtained from (**2**), and the sign used for W_2 in the checking case is clearly the correct one. To return to the example previously given, for wattmeter readings W_1 5.60 kw. and W_2 + 0.34 kw., the kv-a. must be 10.87, while for $W_2 - 0.34$ the kv-a. must be 11.54. Since the kv-a. computed from $v\sqrt{3} \times 200 \times 31.1 \times 10^{-3} = 10.78$, it is clear that the positive sign is correct for W_2, and further, that meter inaccuracies, or careless reading, or unbalanced load conditions, or distorted voltage or current, collectively, are producing a discrepancy of less than 1 per cent.

Further examples of the use of this method are given in the table (to the left of the heavy dividing line). The data for these examples were selected from actual runs in which the power factor varied steadily from a low value to something well over 50 per cent, so that for each set of readings the sign of the smaller wattmeter reading was known without question; in each case, except the fifth the particular reading for which the power factor was nearest 50 per cent, and for which, therefore, the method would most likely fail, was chosen.

A variation of the method which may be more convenient in some cases is the computation and comparison of power factors instead of volt-amperes. Power factor is commonly computed either by the ratio

$$P f = \frac{W_1 + W_2}{v\sqrt{3}\, E_L I_L}, \text{ or by taking the ratio } k = \frac{W_2}{W_1}$$

and finding the power factor on a curve plotted against k.[4] These two values of power factor will agree under the same conditions as the values of volt-amperes. The accompanying curves may be used for the same purpose and they seem even more simple. If the ratio $\frac{W_1}{E_L I_L}$ be computed, the power factor may be read at once from this curve; the other ratio, $\frac{W_2}{E_L I_L}$, should fall upon the other curve at the same power factor. It will be noted that the second ratio, $\frac{W_2}{E_L I_L}$, is used only as a check upon balance, etc.; it is not needed to determine the power factor. And, indeed, the curve itself is not needed to determine the sign of W_2, for the ratio $\frac{W_1}{E_L I_L}$ is always less than 0.866 $\left(= \frac{v\sqrt{3}}{2}\right)$ when W_2 is negative (power factor less than 50 per cent), and is always greater than 0.866 when W_2 is positive (power factor greater than 50 per cent), so that this ratio alone is sufficient unless a further check is desired. Using the data of the previous example,

$$\frac{W_1}{E_L I_L} = \frac{5600}{200 \times 31.1} = 0.900 > 0.866; \text{ therefore,}$$

W_2 is positive, and from the curve, the power factor is 55 per cent; the ratio $\frac{W_2}{E_L I_L} = \frac{+340}{200 \times 31.1} = 0.055$, which indicates a power factor of 54.5 per cent. Other examples of this use of the method are also given in the table; these are to the right of the heavy dividing line.

It is clear that the methods given are but variations of one. The more convenient should be used according to circumstances or personal preference; either one is a very easily applied check upon the readings, the connections, and the sign of the smaller wattmeter reading.

COMPUTATIONS FROM ACTUAL DATA, SHOWING METHODS OF DETERMINING SIGN OF W_2 AND CHECKING READINGS

E_L	I_L	W_1	W_2 (sign known)	$v\sqrt{3}\, E_L I_L$	Kv-a. from wm. taking $+W_2$	$-W_2$	sign of W_2	$\frac{W_1}{E_L I_L}$	sign of W_2	$\frac{W_2}{E_L I_L}$	Power factor from W_1	W_2
201	23.4	3.76	−0.56	8.15	7.03	8.14	−	.799	−	.119	39.0	39.0
200	31.1	5.60	+0.34	10.78	10.87	11.54	+	.900	+	.055	55.0	54.5
215	18.6	3.46	−0.04	6.93	6.88	6.96	− *	.865	−	.010	50.0	49.3
213	20.6	4.06	+0.54	7.61	7.64	8.71	+	.925	+	.123	60.0	60.5
207	15.7	1.82	−1.44	5.64	3.31	5.65	−	.560	−	.443	7.0	6.5
217	18.8	3.56	+0.06	7.07	7.06	7.17	+	.872	+	.015	51.0	52.0

Sample calculation for first line: Column 5, $v\sqrt{3} \times 201 \times 23.4 \times 10^{-3} = 8.15$ kv-a.

Columns 6 & 7, $4 \times 3.76^2 = 56.55$

$4 \times 0.56^2 = 1.25$

Sum 57.80

For $+W_2$, subtract $4 \times 3.76 \times 0.56 = 8.42$

49.38; $v\sqrt{49.38} = 7.03$

For −, add $57.80 + 8.42 = 66.22$; $v\sqrt{66.22} = 8.14$

Column 8, since column 7, using $-W_2$, checks column 5, W_2 is negative

Column 10, Since $\frac{3760}{201 \times 23.4} = 0.799 < 0.866$, W_2 is negative

Columns 12 & 13, power factors read from curves at 0.799 and − 0.119 respectively

*Note: The data in this line are such (W_2 about 1 per cent of W_1) that a certain determination of the sign of W_2 is difficult. While the method gives the correct result in this case, it could hardly be relied upon in general.

4. R. R. Lawrence, op. cit., p. 332.

Sectional Electric Drive for Paper Machines

BY R. N. NORRIS[1]

Synopsis.—This paper describes a system of electric control for sectionalized electric drive which makes use of a mechanical differential. Further, it discusses the drive of the constant-speed end of the paper machine and the general advantages of electrical sectional drive for paper mills. Some figures are given on the power consumption of several classes of mills. The type of drive described has been used for some time in Europe and Canada and it has now been successfully introduced in the United States.

IN this paper will be described a system of sectional electrical drive which utilizes a mechanical differential as the basis of its control. First, this particular type of system, called the Interlock System, will be described and this will be followed by comments on the drive of the constant-speed end of the paper machine, with statement of the advantages of sectional driving in general.

Like all other sectional electric drives the Interlock installation consists essentially of a d-c., compound-wound, interpole generator with an exciter, which exciter supplies the excitation current to the field circuit of the generator and also the field circuits of the several section motors.

It is essential that the generator and exciter be designed to give good regulation under varying load conditions and that voltage regulators be provided to maintain a steady voltage in order to compensate for variations in load or speed of the prime mover.

Fig. 1 is a schematic diagram and layout of a typical installation showing the section motors at the couch, press, dryers and calender sections of a newsprint machine. This illustration does not show the reel or winder sections, but the reel and additional calender sections or smoothing roll sections, etc., can be driven in a similar manner, and the sketch serves to show the arrangement of the drive in general.

Each section of the paper machine is driven by a compound-wound interpole d-c. motor, which may be either directly coupled to the paper machine in-driving shafts or coupled thereto through some form of gear unit—double helical, worm, chain, etc. Sometimes a very convenient arrangement is to use direct-coupled motors for the heavier powers at couch, dryer and calender sections, and geared units at the press sections.

Fig. 2 shows direct-coupled motors driving a 234-in., 1200-ft. per min. newsprint machine. The sectional drives are housed in a separate room, the in-driving shafts of the paper machine passing through the walls into the machine room proper.

Fig. 3 shows an all-geared arrangement of Interlock drive, and Fig. 4 shows the semi-geared arrangement referred to above. Fig. 5 is a line drawing of a direct-coupled motor and also shows control unit.

In large newsprint machines the dryer sections consisting as a rule, of 40 to 46 cast-iron cylinders, five or six feet in diameter and up to 240 in. face, are usually geared together and driven by motors driving through two pinions on to the same load.

However, the arrangement of the machine, whether direct-coupled, gear-driven, or, as here termed, semi-geared, is a matter of detail which may vary with the particular case in question.

As illustrated by Fig. 1, a d-c., adjustable-voltage generator, *G*, supplies the necessary power to the section motors, *A* 1 to *A* 7. This generator is separately excited, and the exciter also supplies the excitation

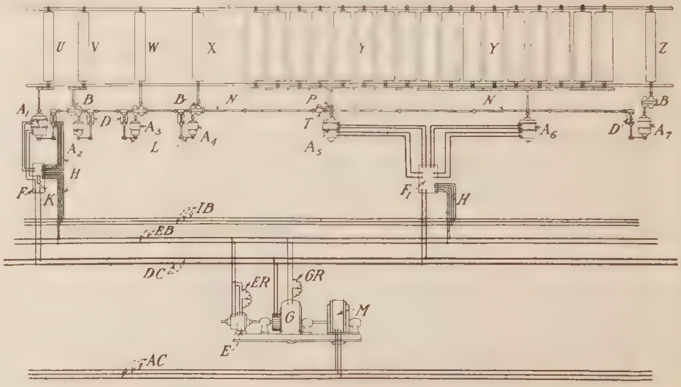

FIG. 1—SCHEMATIC DIAGRAM AND LAYOUT OF TYPICAL INSTALLATION

A.	Section motors	U.	Couch press
B.	Speed reduction gear	V.	1st press
D.	Differential regulator	W.	2nd press
E.	Exciter	X.	3rd press
F.	Motor starting panel	Y.	Dryer section
F.	Dryer starting panel	Z.	Calenders.
G.	D-c. generator	DC.	Main d-c-bus, 500 or 250 volts
H.	Contact and field connections	EB.	Exciter bus, 250 volts
K.	Armature starting resistance	ER.	Exciter field rheostat
L.	Cone pulleys and belt for adjusting draw	GR.	Generator field rheostat
M.	Main synchronous motor	IB.	Interlock bus, 250 or 125 volts
N.	Master shaft	AC.	Main a-c. bus
P.	Chain drive		
T.	Bevel gears		

current to the field circuit of the several section motors.

*A*1 to *A*7 represent the various section motors, which, on the couch, and the two dryer sections, are direct coupled to the intake shafts. On the three press sections and the calender section, a single reduction herringbone gear is employed. For purposes of simplicity no main switchboard is shown in this illustration; however, a main switchboard is provided between the generator and exciter and the main busbars, *D C*, and exciter busbars, *E B*. On the couch section is shown one of the motor starting panels, *F*, with the

1. Managing Director, The Harland Engineering Co., of Canada.

Presented at the Regional Meeting of District No. 2 of the A. I. E. E., Cleveland, Ohio, March 19, 1926.

necessary connections from the field and armature circuits of the motor, and the differential regulator. D; $F1$ is the starting panel for the dryer motors.

Speed adjustment within the desired range of the paper machine is obtained, in the case of large newsprint machines, entirely by variation of the generator voltage which is applied to the section motor armatures.

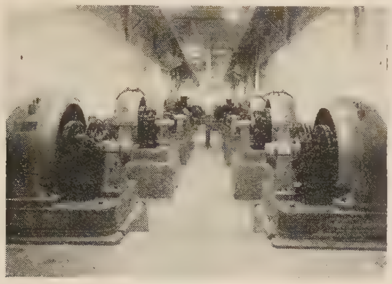

Fig. 2—Direct-Couples Motors Driving a 234-in.,1200-Ft. per Min. Newsprint Machine

In book-paper machines, or other machines requiring large speed ranges, this speed adjustment is obtained by a combination of generator voltage regulation as above and variation of the field strength of the section motors. The whole of this speed adjustment is obtained from a combined regulator which is operated by one handwheel or by remote-control, push-button operation.

The arrangement of the Interlock control system shown in Fig. 1 consists of a master shaft N, located in any convenient place, and extending the entire length of the variable speed end of the paper machine. This master shaft transmits practically no power, as it is only a governor shaft. The power required to drive the master shaft is negligible, and the whole shaft, with the differential regulators but without the draw control belts in position, can very readily be turned by hand from any point of the shaft. At each section, the differential control gear, D, is inserted.

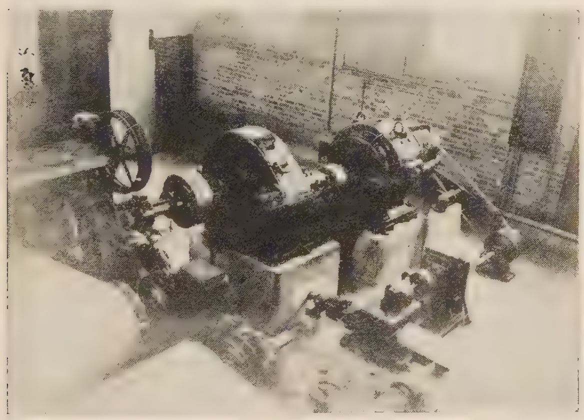

Fig. 3—Interlock Drive in Operation on Third Press Section of 234-in., Newsprint Machine, 600/1000 ft. per Min

In Fig. 1 the shaft is shown passing underneath the reduction gear units, but it, of course, has no connection with these units and is simply shown in this position as being a convenient position for it.

It can be placed in any convenient position—under the floor if desired, with the regulator equipment suspended from the ceiling,—and if the master shaft is an insuperable difficulty either in the layout of the plant at the back of the paper machine or in reality in the mind of the prospective user, then it can be replaced by a synchronous generator and synchronous motor at each section; but in the author's opinion the shaft is the better drive from a point of simplicity and reliability and provides a more rigid and positive drive for the control units.

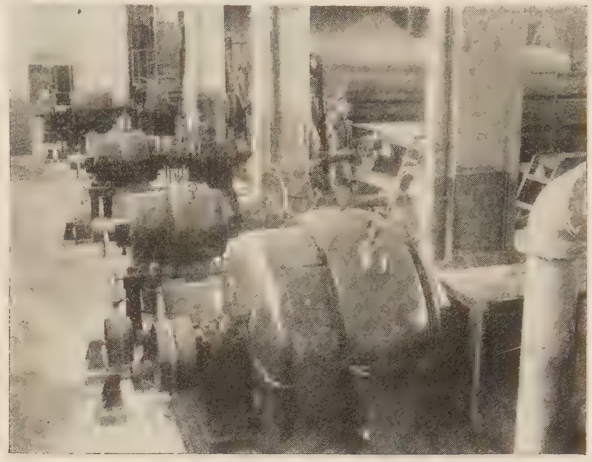

Fig. 4—Semi-Geared Arrangement of Interlock Drive

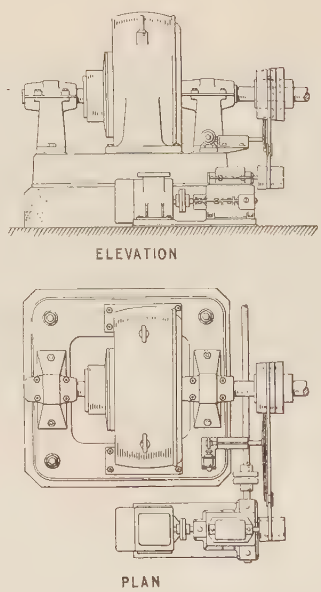

Fig. 5—Showing Direct-Coupled Motor and Control Unit

The master shaft can be driven by either a small, separate electric master motor or from one of the sections of the paper machine, preferably the dryer section, as shown in Fig. 1. This master shaft when driven from the dryer sections is driven by means of a small chain

drive or a small geared drive, whichever happens to be the more suitable for the layout in question.

A diagrammatic illustration of the differential-control apparatus, geared to the master shaft at each of the sections to be controlled is given in Fig. 6. This

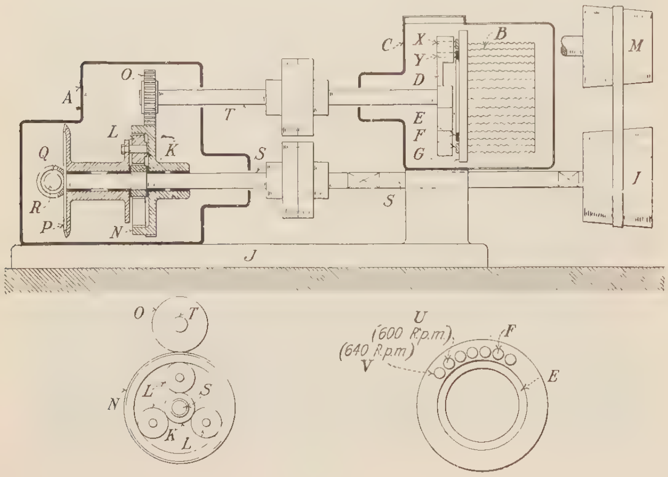

Fig. 6—Diagrammatic Illustration of Differential Control Apparatus Geared to Master Shaft at each Section to be Controlled

differential control consists of bevel gear, P, free to revolve on cone pulley shaft, S, and a bevel pinion, Q, which is mounted on the master shaft, R. Attached to the bevel wheel, P, are three planetory pinions, L, which mesh with the sun wheel, K, the last named being keyed to the cone-pulley shaft, S; the pinions, L, also mesh with the internal teeth of the annular ring, N, which turns freely on shaft, S. Around the outside of the annular ring, N, are teeth that engage with another spur wheel, O, mounted on shaft, T, this shaft being connected through a coupling to a shaft carrying the brush arm, D, in the automatic differential regulator C.

If the shaft, S, carrying the cone pulley, I, which is driven by the section motor, runs (in the opposite direction) at the same speed as the bevel gear, Q, located on the master shaft, then there will be no re-

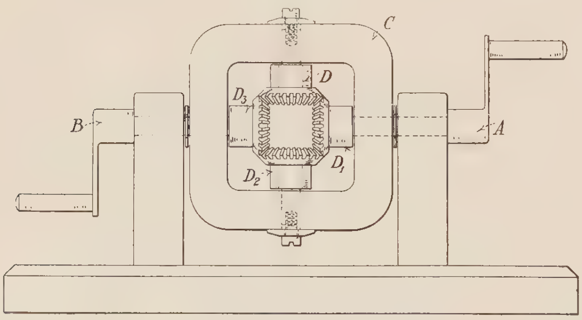

Fig. 7—Bevel-Gear Differential

sultant movement of the annular ring, N; but however slightly these two may vary in angular position relative to each other, a correct and instantaneous response is given on the annular ring, N, and coincidentally on the wheel, O, which is driven by the annular ring. The bevel pinion, Q, is driven by the master shaft in each case, and the sun wheel, K, is driven from the cone pulley through the section motor itself, which must be controlled in each case. Therefore, any tendency of difference in angular relation between the master shaft and the motor to be controlled is instantaneously reflected on the annular ring.

An epicylic train of wheels is an elusive creature when it is desired to know exactly what takes place, and to more readily grasp the simple and effective nature of the control it is easy to look upon it as a bevel gear differential as Fig. 7. This consists of a small frame, C, with four small bevel gears, D, $D1$, $D2$, $D3$, all of the same size and having the same number of teeth. Gears, D and $D2$, turn on journals that are attached to the frame C; gear $D1$ is keyed to the shaft, at the other end of which is keyed the handle B; and gear $D3$ is keyed to a shaft, at the other end of which is keyed the handle, B; the frame C is free to turn on these two shafts. Suppose the frame to be held stationary and handle A to be turned clockwise; then, gears D and $D2$ will turn in opposite directions, and will cause gear, $D3$ to turn in a direction opposite to that of gear $D1$, which is keyed to the same shaft as the handle A. The two handles A and B will, therefore, turn in opposite directions at the same speed in revolutions per minute.

Now if the frame, C, be free to turn and handle, A

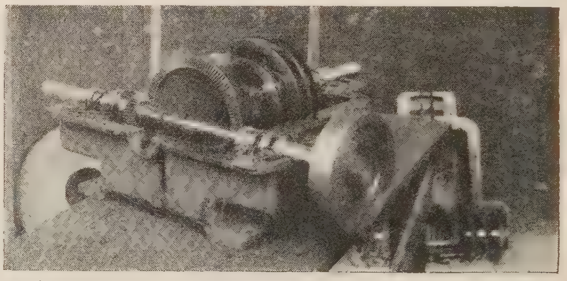

Fig. 8—Epicyclic Interlock Differential with Cover Removed

and B, together with gears, $D1$ and $D3$, are turned in opposite directions at the same speed, the frame C will remain stationary, the conditions then in so far as the revolutions of the gears are concerned, being exactly the same as they were when the frame was held stationary. If, on the contrary, while A makes 100 turns, B makes one turn more or less than this, *i. e.*, 99 or 101 turns, the frame, C, must make half a turn forwards or backwards, the same result that would be had if $D1$ were stationary and handle, B, made one turn.

The angular displacement has nothing to do with time; it depends only on the difference between the number of turns made by the gears, $D1$ and $D3$, regardless of whether this takes one minute or one year. Therefore, if in *any* period of time, gear $D1$ has an angular velocity of 1 deg. greater or less than gear $D3$, the frame C must be displaced ½ deg. from its initial position.

The Interlock system of control is merely the application of this principle to the regulation of the speed of the electric motor connecting a single field rheostat to the third member of the differential, which, in the epicyclic differential Fig. 6, is in the ring, N, and is so connected [illegible], O, shaft, T, and coupling, X.

Fig. 8 shows the epicyclic Interlock differential with the cover removed, and Fig. 9 closed, and it gives a good idea of the robust construction. The gears all

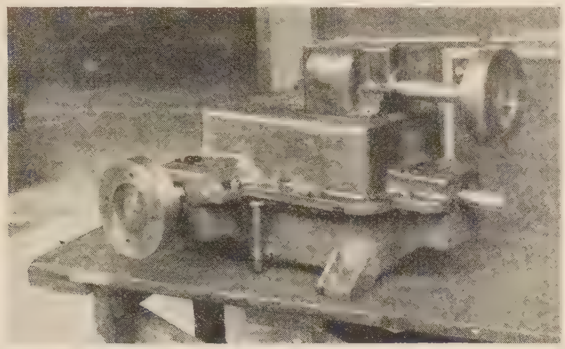

Fig. 9—Epicyclic Interlock Differential with Cover Closed

run in oil, and being enormously large in comparison to the power required, they will run indefinitely without wear. In fact, after four years' operation at 24 hours per day on a large Canadian newsprint installation, the gear teeth still show the signs of the hobbing cutters which milled them out of the solid.

The field regulator portion of the control contains a large number of resistance units which are cut in and out of circuit of the motor field, the circuit being completed through the brushes X and Y which travel over a number of contacts F and form a complete circuit through the brass ring contact E. In practise, the brush arm, D, quietly breathes between the two contacts, of which there are 80 to 100 on the regulator.

The accuracy with which the desired speed is required is so great that if there were a million contacts instead of 80, they would not suffice to have one for every flicker in speed; the brush would steadily breathe but the movement would still be between the contacts, one on each side of the desired speed. Referring to the lower right hand part of Fig. 6, suppose that one of these contacts U represent 600 rev. per min., on the motor, that the next contact, V, represent 640 rev. per min. and that a speed of exactly 620 rev. per min. on the motor were required; then the brush arm would be quietly breathing between the two contacts U and V, spending sufficient time on either contact to produce an average field that will give a perfectly steady motor speed of 620 rev. per min., the speed that was desired for the moment. Should this desired speed be 635 rev. per min. say, then the action is exactly the same as before, except that the arm spends a fraction more time on contact V than on contact U.

If the load varies on any motor, it will immediately tend to speed up or slow down, which will produce a tendency to change any angular variation between the two halves of the differential. The annular ring, N, will move and the rheostat arm, D, will take up this new position to suit the load in question.

The control is absolutely automatic and instantaneous for all conditions of load which may occur, and no hand adjustment of the motor field strength is required for any load change which does occur such as happens at the press sections, for instance, when the weights are changed, or at the couch section when the vacuum is altered.

If the machine operator desire to change the draw between sections of the paper machine, he has only to move the belt on the cone pulley, I, and cone pulley, M, Fig. 6, attached to the motor shaft; the motor is then trying to drive, K, at a speed that is different. This immediately sets in motion the annular ring N, which comes to rest again in a moment, after moving through a few degrees of arc, enough to alter the resistance in C; harmony is then once more established, and the motor, running at a different speed, as desired, is still driving the sun wheel, K, at exactly the same speed as that of the bevel pinion. The 1½-in. belt may be shifted on the cone pulleys by a hand-wheel or by remote control of a fractional h. p. motor that operates the belt-adjustment gear.

Starting up of the respective section motors is obtained usually by means of automatic push-button-operated contactor motor-starting panels. The push buttons can be located anywhere and are usually on the front of the paper machine at the respective sections, the panels themselves being arranged usually as a switchboard in a substation preferably alongside the

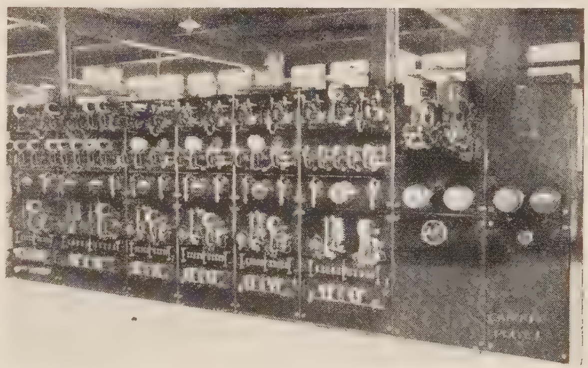

Fig. 10—Typical Switchboard for Automatic Push-Button Operated Motor Starting Panel

generator and main switchboard; Fig. 10 shows a typical switchboard of this nature.

The starting panels are provided with resistance units capable of giving very slow crawling speeds which are required when putting on new Fourdrinier wires or felts at the press sections or the dryer sections, and also for the purpose of inching round the various sections for inspection purposes.

Each section can be started, run at slow speeds, or stopped, independent of the other sections, without

interfering with any of the other sections. They will all continue to run at the predetermined speed. Should the master section shut down—whether it is the dryer sections, or a small master motor—all the other sections automatically still continue to run at the speed at which they were first operating.

Of course, for the time being, while the master section is standing, the Interlock is not in operation, but immediately the master section has again been brought to full speed the other sections automatically go into interlock.

These conditions are all made by the means of simple automatic devices.

Motors

All motors, whether for direct-coupled machines or for geared installations are totally enclosed and supplied with forced ventilation. This is a distinct advantage at the back of the paper machine, as behind the dryer sections high temperatures are met, and behind the wet end of the paper machine at the couch and press sections a great amount of splashing of water mixed with paper stock occurs which is not good for the windings of any electric motor. Furthermore, at times careless use of a hose by some operator may ruin a motor. All this is safe-guarded against by the use of totally enclosed machines.

This Interlock sectional electric drive which was developed by the Harland Engineering Company has been in successful use since 1914 when it was first installed in Scotland on a small machine having a wide speed range of ten-to-one. During the four or five years previous to this installation there were two sectional electric drives in operation in Great Britain. One of these was not altogether successful and was replaced by mechanical drive. The other was converted to the Interlock differential-control system and is the drive in Scotland referred to above. This equipment is still in operation. Since the installation of this equipment, constructional improvements in mechanical and electrical details have been made as a result of experience, but the principles of control and operation have not been changed.

Before passing from sectional electric drive reference will be made to the driving of the constant-speed end of the paper-machine, which seems liable to suffer from neglect owing perhaps to the tremendous interest that has been focused on its sister part.

The paper-machine drive has always been separated into two groups,—the constant speed part, and the variable speed end. The development of the sectional electric drive has provided for the latter, but there appears to be little movement as yet to study and change driving arrangements of the constant speed end. Where a separate driving unit is provided it is quite usual to have two generators and exciter, all driven together, consisting of a d-c. generator, its exciter (which also excites the sectional motor fields) for the variable speed end, and an alternator to provide a-c., three-phase supply to operate the constant speed end. This constant speed end may be driven by one motor, or it may be divided into groups, but no attempt seems to be made to adjust the running speed of its elements to suit the changing speed of the paper machine.

A little progress has already been made in one or two mills in so far that in a few cases the pumps, etc., are being driven by separate motors, thus eliminating belts as far as possible. For this purpose the d-c. motor has been employed, which has wherever possible been direct coupled to pumps, and which allows a moderate amount of speed control by shunt regulation, thus enabling the speed of the pump to be adjusted to suit the operating speed of the paper machine itself. For such a purpose, direct current clearly has an advantage, and the author believes will gradually be more widely adopted.

It is true that some portions on the constant speed part have been initially conceived and developed with a drive from a steam engine or a counter shaft in mind, and perhaps do not seem to be specially suited for direct coupling to a motor, but, doubtless with the development and more extended use of an individual drive on the constant speed end, designs which the business seems to demand will gradually be evolved. In such matters engineers do not usually lag far behind. With such an arrangement the speeds of the various pumps can be adjusted to suit the output required of them, which to a moderate extent varies with the speed of the paper machine. In this way economies in power can be attained and it is believed other advantages also will result. It will be evident that the control of this part of the machine will be more complete than is otherwise possible.

The following table gives averages of some hundreds of power readings taken from time to time on various machines. The first row covers readings on 14 machines of similar size in operation, and the second row, 6 machines. The others are averages on selected individual machines:

Width & Type of *M/c.*	Average Speed Ft.per min.	Electric H. P. Input to Motor per inch width of Machine per 100 Ft. per Min. Paper Speed									
		Couch	1st. Press	2nd. Press	3rd. Press	4th. Press	Dryers	1st. Cal.	2nd. Cal.	Exciter.	Total
23-4in. News	875	0.039	0.016	0.023	0.022	..	0.060	0.036		0.0057	0.2017
166-in. News	750	0.054	0.029	0.027	0.0	..	0.674	0.650		0.009	0.243
168-in. Kraft	675	0.039	0.027	0.020	0.017	..	0.041	0.036		0.008	0.188
148-in. Book	520	0.046	0.044	0.026	0.044	..	0.035	0.031	0.068	0.008	0.300
148-in. Tissue	230	0.017	0.041	0.017		..	0.047	0.043		0.006	0.171

From several readings obtained from machines having mechanical drives with single motor the average e. h. p. per inch of width for 100 ft. per min. is 0.35 e. h. p.

Then there is the very interesting side of the question relating to the effect of sectional driving on the thermodynamic efficiency (a) of the paper machine itself—(b) of the paper mill as a whole,—as a result of the saving in power effected by sectional driving.

From the power table just given, it will be seen that a 234-in. paper machine, operating at 1000 ft. per min. would require 472 e. h. p. A mechanically operated machine operating at the same speed would require about 819 e. h. p.

Assuming that the average output of paper from the machine is 125 tons per twenty-four hours, and that the average steam requirements for drying the paper are 3.75 lb. of steam per pound of paper, then we get a steam requirement in the drying cylinders of the paper machine, 38,900 lb. of steam per hour.

A steam turbine operating under normal conditions usually met with in a paper mill would have a water-rate of about 38 lb. of steam per e. h. p.-hr. allowing for generator efficiencies, so that by utilizing to the fullest extent the power in the steam required in reducing it from the normal pressure to the pressure required for drying in the paper machine cylinders we can obtain approximately 1000 e. h. p.

Now, if the paper machine is driven mechanically, the balance of horse power so obtainable (181. e. h. p.) would hardly justify the installation of an additional generator to supply the excess power to the constant-speed end of the machine, but the balance of power obtainable by using sectional drive, 528 e. h. p., is sufficient to justify this and is usually enough to drive the whole of the constant speed end of the paper machine. This renders the paper machine an individual unit, which has many advantages.

Sectional driving of paper machines has also had its effect upon building design by reducing the cost of basements and saving space.

The foregoing does not pretend to deal with the general advantages to be obtained in the use of sectional electric drive as compared with mechanical drive. These are becoming so generally well-known that it is only necessary to outline briefly a few of them—such as the elimination of belts and ropes, and their consequent very high up-keep costs; the saving of power as is shown on the power figures given above; the very much steadier speed control between sections of the paper machine which result in a better quality and production of paper from a given machine with a given quality of stock supplied to the machine.

Each section of the paper machine is made a separate unit and with electrical indicating instruments it is possible to detect faults which may arise on the paper machine itself which allows of investigation and probably rectification of the trouble before it becomes serious, whereas with mechanical drive very probably the first indication of trouble is when the trouble has become serious enough to necessitate expensive repairs.

The greater ease in handling the paper machine by the paper mill operators is very marked and needs to be experienced to be realized. The absence of ropes and belts on the back side of the machine makes the machine more accessible, which all helps in the upkeep and maintenance of the plant and reducing life hazard.

Due to the very even starting torque exerted by electric motors, particularly of the d-c. type, dryer gear life is increased as compared with the mechanical drive where power application of the dryer gears is usually by clutch or snatching of cone pulleys which puts sudden stress on the gears.

These notes have been put together on the assumption that they will be read to those who have some knowledge of paper machines and are interested in present and future operation and development. There is to my mind a great field in the United States for conversion of old mechanically driven machines to sectional drives and although I expect there are many paper makers who will disagree with me, I maintain that there are very many advantages to be obtained in doing this.

One, of course, still meets the man who says the mechanical drive is good enough and he is clearly right from the standard of his own point of view. Everybody knows that mechanical drives have made and will still make good paper. In the beginning it was the large powers and high speeds required by the large newsprint machines which forced forward this subject of sectional driving, although its actual development was accomplished before the advent of the large high-speed machine.

The steady increase in the size of newsprint machines finally made sectional driving a necessity.

When its reliability became established, it made wide machines and high-speed machines more readily available than formerly. Its advent also has apparently had an influence on the design of the paper machine itself as regards the widths and speeds at which it can be built.

The reliable nature of the drive in operation on newsprint machines has been proved and has demonstrated also that for the small book machines, etc., the same good results can be obtained: in fact, it is becoming more general, and nearly all new book machines are fitted with sectional drive. As stated before there is a big future for the conversion of existing machines to sectional drive.

In this connection it is interesting to consider that some form of sectional drive has been constantly the subject of research by independent peoples in different parts of the world; contemporary with the work which we were doing in Great Britain, other people were carrying on similar experiments on this Continent and in Europe. All these experiments, the author believes, were made quite independently of each other showing a widespread belief in the necessity and usefulness of sectional drive.

Can the Thermal Capacity of Electric Machines
Be Made a Simple and Practical Element of Rating?

BY A. E. KENNELLY*

Preface

THE subject of this paper has been suggested to the U. S. Committee, by the Council of the I. E. C., as suitable for a report at this 1926 meeting, and has been assigned to the writer for preparation. The writer does not claim any authorization from the U. S. National Committee to present its views officially on the subject. He merely submits the paper as expressing personal opinions, aided, however, by the records and reports of a certain group of engineers who have given special attention to the thermal constants of electric machines, and who are mentioned in the following text.

Brief Answer and Purport of the Paper

It is believed that the thermal constants of electric machines in the variable regime, (especially their binary time constants), can, in many cases, be used in a very simple way for practical operating purposes. It is not, however, recommended that such thermal constants should be introduced into the rating of machines at the present time. It is, nevertheless, recommended that these thermal constants should be regarded as useful subsidiary information concerning machines, until such time as engineers may have become more generally familiar with their application and use. All machines do not seem equally subject to their useful application. Attention should be called to the practical service that the purchasing and operating engineer may derive from the thermal constants of machines. It seems likely that, at some future time, after the matter has been more thoroughly investigated by designers, manufacturers, testers, and operators of electric machinery, these thermal constants, including thermal capacity, may be found sufficiently important and reliable to be promoted from the present category of useful subsidiary information, to the category of rating constants of machines.

It should be pointed out that but little of the technical material in this paper is new. It is mainly collected here for convenience of reference.

Thermal Constants of Electric Machines may be divided for convenience into two classes, namely,

1. Steady-regime constants.
2. Variable-regime constants.

Class 1 may be considered to contain the following, for any machine or element of the same (such as field, armature, internal or external part of winding, stator rotor, commutator, bearing, etc.)

a. Hottest-spot maximum safe temperature.

b. Maximum accessible measurable temperature.

c. Ambient temperature, θ_a.

d. Instantaneous temperature rise of machine or element θ.

e. Instantaneous temperature, $\theta + \theta_a$.

f. Ultimate temperature rise under continuous rated load, Θ.

All of the above constants enter either directly or indirectly into the continuous rating of a machine from the thermal standpoint, and need no discussion here.

Class 2 may be considered to contain the following thermal constants for any machine or element:

A Ultimate temperature rise characteristic $\Theta - P$, under different sustained percentages of rated load.

B Time constant or constants of machine or element τ hours or minutes

C Thermal capacity of machine or element k watt-hours per deg. cent. temperature rise above stationary ambient.

D Specific thermal capacity of material in a machine or element—watt-hours per kg. and deg. cent.

E Dissipation constant of machine or element s watts per deg. cent. temperature rise.

The variable-regime thermal constants (*A*) to (*E*) are the main subjects of discussion in this report.

Utility of Variable-Regime Thermal Constants

Characteristic A. The most important of the class 2 here considered is probably *A*, the ultimate temperature rise characteristic $\Theta - P$. This is a characteristic curve connecting the ultimate temperature rise of the machine, presumably at its max. accessible temperature location, for different percentages of rated load. When drawn on logarithm paper, such a curve usually approximates to a straight line over a moderate percentage range of load. Thus, in Fig. 1, the particular machine supposed to be there designated develops an ultimate temperature rise of 40 deg. cent., in a specified element, at continuous rated load. It also develops 50 deg. cent. rise at 1.15 times rated load, and 76 deg. cent. at 1.5 times rated load, if the straight line characteristic *A O C* is adhered to over that range. This straight line rises 1.6 units of ordinates in one unit of abscissa length; so that this straight line represents a temperature rise increasing as the 1.6th power of the load, over the range it may be taken to cover.

An operating engineer, knowing the continuous rating of the machine, can ascertain with the aid of such a characteristic the temperature rise of the element considered, over a certain range of steady loads, from, say, 0.50 to 1.5 times rated load. The maker of the

*Honorary Secretary of the U. S. National Committee, I.E.C.

A report presented to the International Electrotechnical Convention at its U. S. Meeting in April 1926.

machine may not have made ultimate temperature rise measurements at different steady loads; and therefore may not be prepared to give this $\Theta - P$ characteristic. He will in many cases, however, have secured such a series of three or four different ultimate temperature rises, at different percentages of rated load, on some similar machine of the same dimensions and speed. The purchasing engineer may be able to obtain this auxiliary information from the maker, and so construct

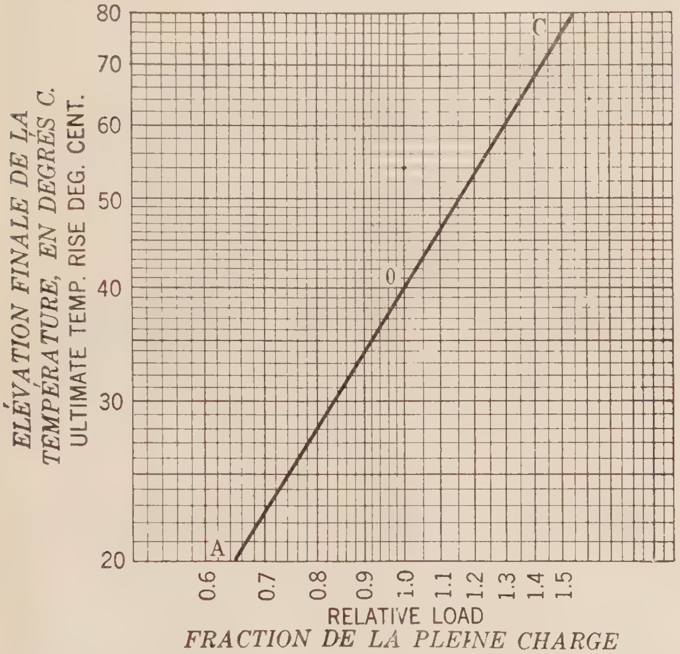

Fig. 1—Approximate Straight Line Relation Between Ultimate Temperature Rise and Steady Load for a Particular Dynamo Machine

a $\Theta - P$ characteristic which is likely to be fairly reliable. The operating engineer may subsequently be able to check this characteristic from the observed behavior of the machine under some particular steady load or loads in service.

Time Constants B. It is well known* that when a machine passes from one steady load to another, at constant ambient temperature, the temperature rise of any element will change, in the simplest case, with time, according to a simple exponential curve or time-constant curve. Owing to complexity of thermal relations among the different elements of a machine, the temperature rise may depart materially from a simple exponential curve; but in many cases it conforms to such a curve sufficiently closely for practical purposes.

Two principal varieties of thermal time-constant present themselves:

1. The exponential time constant τ_ϵ, fundamental in the theory of such curves, but awkward to use.

2. The binary time constant τ_2, suitable for practical use.

In any exponential curve, the exponential time-constant τ_ϵ is that interval of time during which the temperature rise comes within $1/\epsilon$, or 1/2.718, or 36.8 per cent, of the ultimate rise. In a period of $2\,\tau_\epsilon$, the rise will come within $1/\epsilon^2$, or about 13 per cent, and in $3\,\tau_\epsilon$ within $1/\epsilon^3$, or about 5 per cent, of the ultimate rise.

The binary time constant τ_2 is that interval of time during which the temperature rise comes within 1/2, or 50 per cent, of the ultimate rise. In a period of $2\,\tau_2$, the rise will come within $1/2^2$, or 25 per cent, and in $3\,\tau_2$ within $1/2^3$, or 12.5 per cent, of the ultimate rise.

Fig. 2, which is drawn on arith-log paper, shows the attainments and deficiencies at any number up to four exponential or binary time constants. These lines are straight. Thus after four exponential time constants, the attainment is about 0.982, or 98.2 per cent, while the deficiency is 0.018, or 1.8 per cent. Similarly, after the lapse of four binary time constants, the attainment is 0.9375 or 93.75 per cent and the deficiency $^1/_{16}$, or 0.0625 or 6.25 per cent. The two time constants are always connected by the relation

$$\tau_2 = 0.69315\,\tau_\epsilon \quad \text{or} \quad \tau_\epsilon = 1.4427\,\tau_2 \text{ hours} \qquad \textbf{(1)}$$

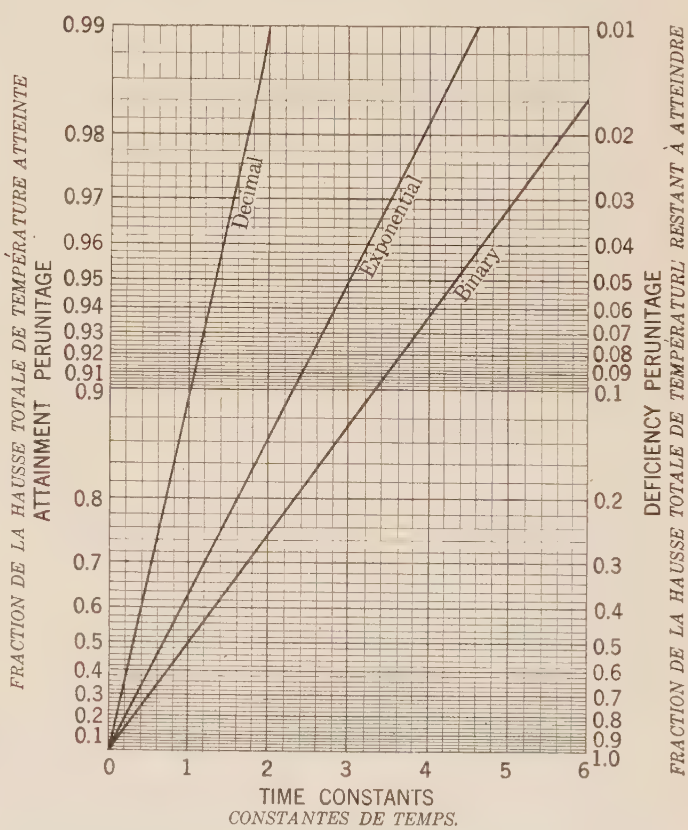

Fig. 2—Attainments and Deficiencies in Terms of the Different Time Constants

so that if the exponential time constant is known, the binary constant is always approximately 70 per cent of it.

The binary time constant τ_2 of a modern rotary dynamo machine ordinarily lies between 10 minutes and 40 minutes, and does not vary greatly with the size or rating of the machine. If we take a mean value of say 25 minutes, and assume that the temperature rise of the machine element considered follows a

*Bibliography 1, 2, 5, 13, 14, 15, 17, 18.

time-constant curve, then when the load is suddenly changed from one steady value to another, the characteristic $\Theta - P$ curve enables the corresponding change in ultimate temperature rise to be predicted. Suppose that the change will be ultimately 30 deg. cent. Then in τ_2, or 25 minutes, the rise will be 15 deg. cent., in $2\,\tau_2$, or 50 minutes, it will be $15 + 7.5 = 22.5$ deg. cent., in $3\,\tau_2$, or 75 minutes, it will be $22.5 + 3.75 = 26.25$ deg. cent., and so on. After $6\,\tau_2$, or 150 minutes, the change will be for practical purposes complete.

An operating engineer may be able to utilize the time constant of a machine in an emergency. He may want to carry a temporary overload without overheating his machine. He knows that he can carry such an overload during a period of one time constant, without attaining more than half the temperature rise due ultimately to that load, provided that the element of the machine considered has this margin of temperature below the danger point, and that the curve of heating is exponential; also that no other element will rise more quickly.

Although rotary machines have binary time constants usually well below one hour, some transformers and particularly, air-cooled, oil-immersed transformers, have time constants of three or four hours. The period during which a temporary overload can be maintained with due precautions, in an emergency, is thus correspondingly increased with such transformers.

When the temperature rise of a machine or element is exponential, it becomes easy to predict the course of the changing temperature when the $\Theta - P$ characteristic and the binary time constant are given, if the load is changed abruptly from one long continued steady value to another. If the load is changed in a less simple way, so that one thermal transient is started before the preceding transient or transients have been substantially terminated, the predetermination of the corresponding temperature becomes more complex. As is well known to designers of traction motors, the resultant curve of θ against time is obtainable from the superposition of a plurality of single exponential curves.

Significance of the constants C, D and E. These variable-regime thermal constants are not at present of much use by themselves. They may, however, be useful conjointly, in arriving at an estimate of the time constant B. If the time constant can be predetermined with satisfactory precision, a $\theta - t$ test of temperature rise against time becomes unnecessary, provided that it is known that the curve is exponential, and that the ultimate rise is known from the $\Theta - P$ characteristic. The relations between B, C and E are given by the familiar formula:

$$\tau_\epsilon = k/s \qquad \text{hours (2)}$$

or

$$\tau_2 = 0.693\, k/s \qquad \text{hours (3)}$$

The value of k, or the C constant, may be computed theoretically from the weights of the different parts of a machine and their specific heats. In practise, certain empirical constants may have to be used, as in Appendix I. Consequently, a time constant that has been observed, is at present more reliable and satisfactory than a time constant that has been computed; although designers, guided by experience, place confidence in their predetermined time constants.

E. The dissipation constant s is defined by the formula

$$p = \Theta\, s \qquad \text{watts (4)}$$

where p is the power lost in the machine or element during the steady thermal state, after the ultimate rise Θ has been substantially attained. Knowing the power losses, and the ultimate temperature rise corresponding thereto, the constant s can thus be evaluated.

Tests for the Exponential Quality of $\theta - t$ Temperature Rise Curves

The time-constant of a machine can only be utilized to the degree of precision within which the temperature rise curve is exponential, according to the formula:

$$\frac{\Theta - \theta}{\Theta} = \epsilon^{-\frac{t}{\tau_\epsilon}} = 2^{-\frac{t}{\tau_2}} = 10^{-\frac{t}{\tau_{10}}} \qquad (5)$$

where $\frac{\Theta - \theta}{\Theta}$ is the *deficiency*, θ/Θ being the *attainment.* A temperature rise curve $\theta - t$ having been obtained by observation, it is always possible to determine, from inspection, whether the curve is in satisfactory agreement with (5); *i. e.*, whether it admits of time-constant application. It is first necessary that the ambient temperature during the test shall have been kept constant, or that the curve be first corrected accordingly, if it has slightly varied*. The ultimate temperature rise Θ, for the curve must also be forthcoming, either by noting that the test has been maintained for a time sufficient to develop substantially this ultimate rise, or by extrapolating from the curve as in Appendix II, or from preceding temperature-rise tests as recorded in a $\Theta - P$ characteristic.

The time during which the temperature rise θ changes from 0 to $\Theta/2$ deg. cent. is measured along the time axis of the curve. This should be the binary time constant τ_2. In another such time constant, the further temperature rise should be $\Theta/4$ degrees. In the third such time constant, the further rise should be $\Theta/8$, and so on. If these relations hold satisfactorily, the curve may be regarded as exponential, from an engineering standpoint. Strictly speaking, the theoretical requirements for exponential temperature rise are so severe, that they can probably never be fully complied with in any machine. Nevertheless, it is surprising how many machines develop satisfactory time-constant curves in their tests, although the time constant of one element, such as the field-winding, may be markedly

*Bibliography 17.

different from that of some other element, say the armature winding in the slots.

A second test, but much more severe, of the exponential quality of a $\theta - t$ curve, is to plot the deficiency $(\Theta - \theta)/\Theta$ on inverted arith-log paper. Thus Fig. 9 gives a $\theta - t$ curve for a certain 2000-kv-a. air-cooled transformer, the curve being drawn exponentially to fit the observations, according to the formula

$$(50.5 - \theta)\ /50.5 = \epsilon^{-\frac{t}{3.72}} = 2^{-\frac{t}{2.58}}$$

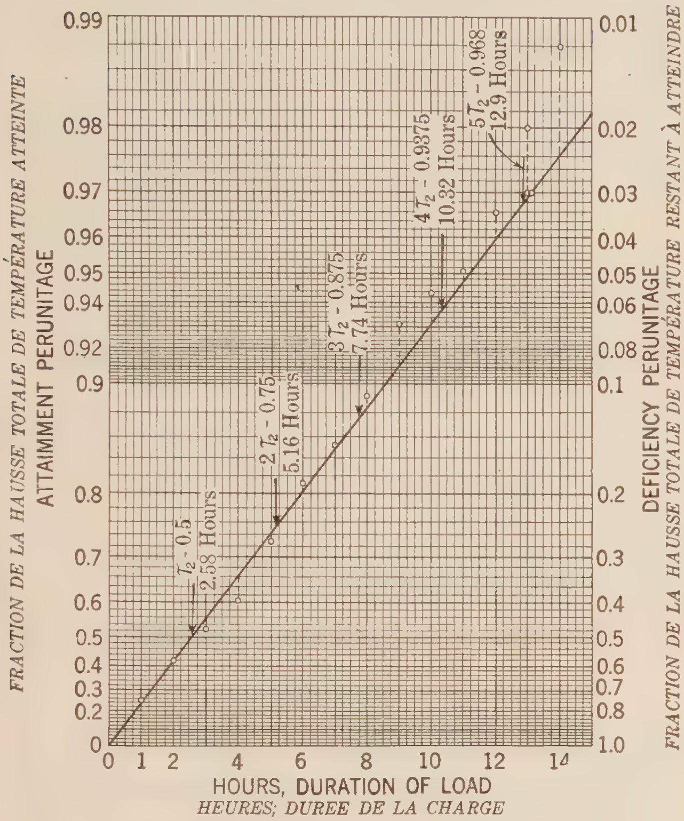

FIG. 3—TEMPERATURE-ELEVATION CURVE OF 2000-KV-A.

Transformer (Fig. 9), drawn on inverted arith-log paper. Straight line, computed exponential rise. Small circles, observed attainments and deficiencies of temperature elevation

It will be seen that the hourly observations conform to this curve satisfactorily. Fig. 3 gives the corresponding plot of the same observations on arith-log paper. The exponential curve is now a straight line; but the observations appear to depart from it much more widely, especially in the upper parts.

In cases where the temperature rise curve departs so far from an exponential law as not to admit of time-constant reckoning, it may sometimes be dealt with in a relatively simple manner by the use of two independent time-constants. Messrs. V. M. Montsinger* and W. H. Cooney† have shown that when, as in many modern air-cooled, oil-immersed transformers, the windings are thermally separated from the core, but the oil is thermally common to both, the temperature rise of the windings above the top layer of oil follows satisfactorily one exponential curve of say 3½ *minutes* binary time constant; whereas the top layer of oil in the transformer follows satisfactorily another exponential curve, of say 3½ *hours* binary time constant.

Prof. Karapetoff has recently given a theory of the temperature rise of a body containing two thermal elements in partial mutual communication.‡ The solution leads to two independent time constants, associated with two final temperature rises, two thermal capacities k_1, k_2 and dissipations s_1, s_2. By means of appropriate tests, these time-constants may be evaluated. Practical results with the method are not yet forthcoming.

EXPERIMENTAL DATA CONCERNING HEATING CURVES OF MACHINES

Figs. 4 and 5 are taken from curves published by Mr. C. M. Laffoon§ on large turbo-alternators, using imbedded temperature detectors in the armature winding. Fig. 4 shows the temperature rise of a 35 megavolt-ampere machine (35 mv-a.), under steady load, with the detectors in contact with the copper armature conductor and within the insulating cover. The curve is drawn exponentially to fit the observations and an ultimate rise of 24 deg. cent. The binary time

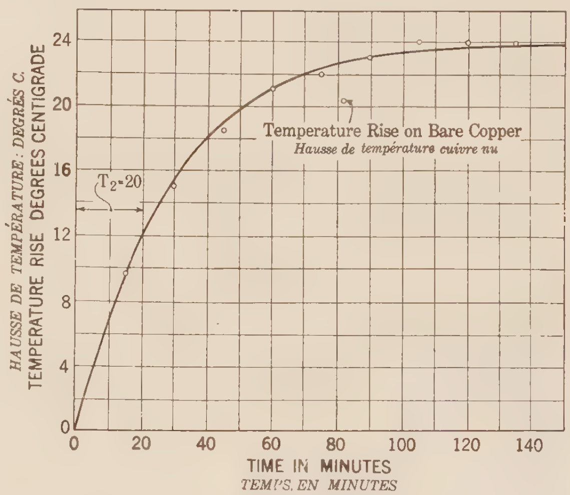

FIG. 4—TEMPERATURE RISE OF A 35,000-KV-A. THREE-PHASE TURBO GENERATOR OPERATING UNDER CONSTANT 75 PER CENT LOAD

Imbedded temperature detectors in contact with the copper winding. Curve computed exponentially to fit the small-circle observations. (C. M. Laffoon, Bibliography 18, Fig. 2).

constant is 20 minutes. The agreement of the observations with the curve is, in general, satisfactory. Fig. 5 shows similar results reported on a 25.9 mv-a. alternator armature using two different positions of imbedded detector; namely, one in contact, as before, with the copper winding, and the other between adjacent coils in the slots; so that an insulating cover separated the

*Bibliography 18, pages 649-651, also 7a.

†Bibliography 19.

‡Bibliography 23.

§Bibliography 18, pages 651, Figs. 2 and 3.

detector from the copper. In the upper curve, the agreement with observations is, in general, satisfactory, but there is a wide departure of the observed temperature rises from the exponential lower curve, during the first hour. This departure is attributable to the effects of the interposed layer of insulation between detector and copper. The time constant τ_2 of the upper curve is 26 minutes, and for the lower curve 38 minutes.

Fig. 6 gives three temperature rise curves reported by

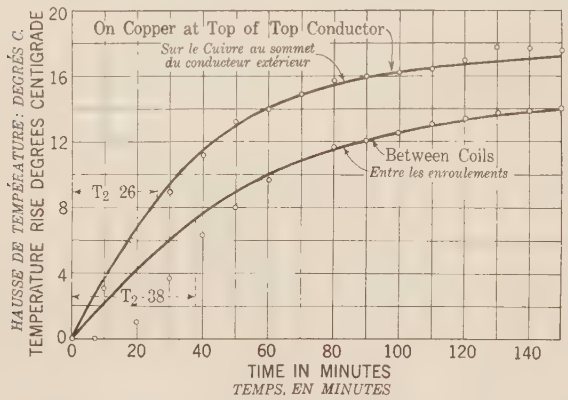

Fig. 5—Temperature Rise of a 25,900-Kv-a. Three-Phase Turbo Generator Operating Under Constant 75.3 Per Cent Load

Exponential curves to fit experimental data. Imbedded temperature detectors. Upper curve for detectors in contact with copper winding. Lower curve for detectors between coils, but outside insulation. (C. M. Laffoon, Bibliography 18, Fig. 3).

Mr. G. E. Luke* for a 35-h. p., d-c. railway motor. The temperature rises were obtained with imbedded thermocouples, and in the case of the armature, through slip rings. The observations conform well with the computed exponential curves. The binary time constant of

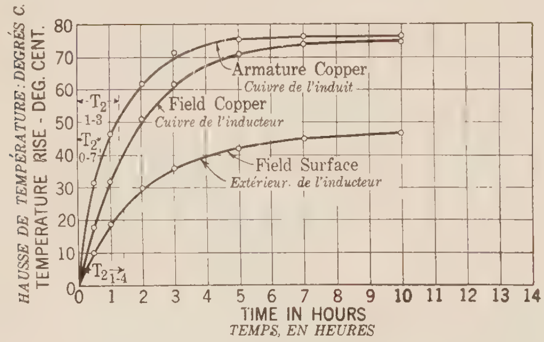

Fig. 6—Temperature-Rise Curves of a 35-H-P., D-C. Railway Motor, 300 Volts, 35 Amperes

Temperature by imbedded thermocouples (armature by slip rings). Curves are exponential to fit observations (G. E. Luke, Bibliography 18, Fig. 9).

the armature copper was 0.7 hour, that of the field copper, 1.3 hours, and of the field surface 1.4 hours. This shows that the location of the hottest-spot temperature in a machine during a temporary overload, may depend upon the time constants of the different elements.

In additional temperature rise tests reported by Mr. Luke, the agreement between the test observations and exponential curves was satisfactory in certain cases but unsatisfactory in others, depending upon the relative mutual dependence of the thermal elements in the structure of the machine.

Fig. 7 gives four temperature rise curves reported by M. O. E. Shirley taken in a series of special thermal tests on a 1100-kv-a., 3000-volt, three-phase synchronous motor. This machine was operated as a synchronous condenser, at substantially zero power factor, starting at ambient temperature, under steady excitation. The ambient temperature remained practically uniform throughout. The top curve represents the rotor field-winding temperature, from volt-ampere measurements. Until after the first hour, the observations conform satisfactorily well with the exponential curve of $\tau_2 = 34$

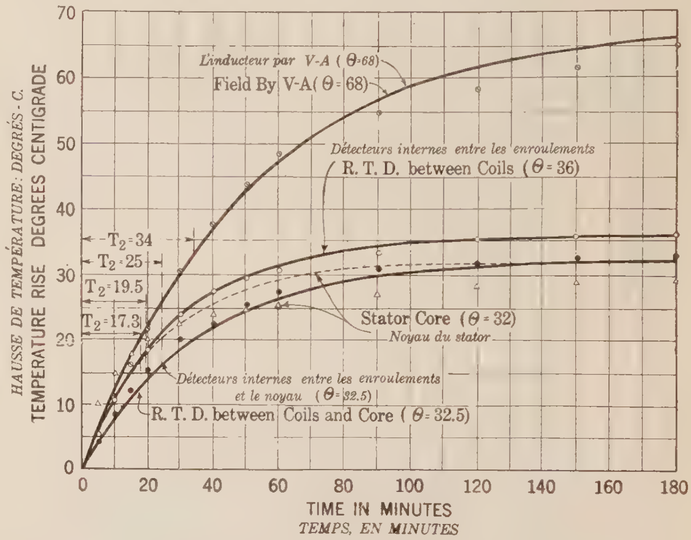

Fig. 7—Temperature-Rise Curves for a 1100-Kv-a., 3000-Volt, Three-Phase Synchronous Motor Operated at Approximately Zero Power Factor or Synchronous Condenser (O. E. Shirley)

minutes. The maximum rise of this field winding exceeds the usual values on account of the over-excitation for zero power factor. The two R. T. D. curves refer to imbedded resistance temperature detectors. The upper of these curves refers to detectors between stator armature coils in the slots, and the lower to detectors placed between stator armature coils and stator core. Both of these curves are in satisfactory agreement with the observations. The former has a time constant of 19.5 minutes, and the latter 25 minutes. The stator core curve, derived from thermometer readings, is not in good agreement with the observations.

Air-cooled, Oil-immersed Transformers. Figs. 9, 10 and 11 give temperature rise curves reported by Mr. W. H. Cooney† from observations on large single-phase transformers tested under conditions of constant load. In these cases the time constant was predetermined by

*Bibliography 18, page 653, Fig. 9.

†Bibliography 19, Figs. 6, 8 and 10.

the method outlined in Appendix I. The curves are exponential with these respective time constants, and conform satisfactorily to the measured temperature rises. They refer to top-oil temperature rise above ambient air. The dissipation constant s in these

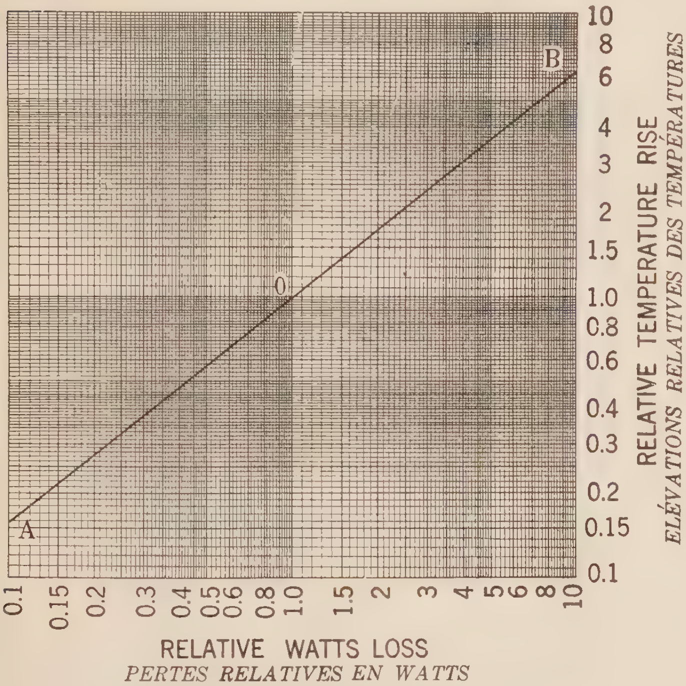

Fig. 8—Approximate Straight-Line Relation on Log Paper Between Relative Temperature Elevation of Top Oil and Relative Loss of Power in Transformer, Referred to the Temperature Elevation at Normal Rated Power Loss

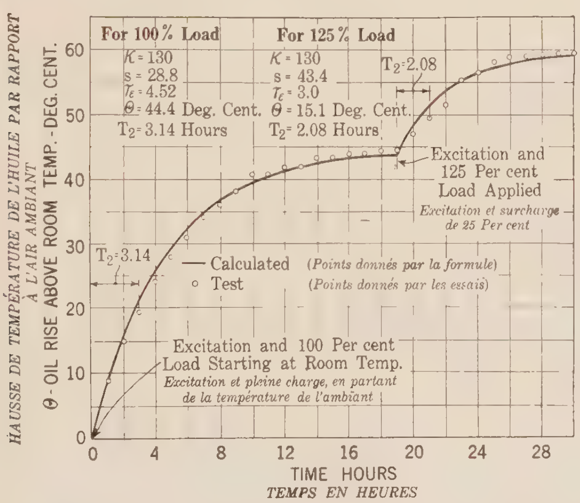

Fig. 9—Temperature Rise of Top Oil Above Ambient Air with Time, in a 75-Kv-a. Transformer, 100 Per Cent Load and Excitation Applied for 19 Hours, Followed by 125 Per Cent Load for 11 Hours More

cases, appears not to have been constant over the temperature range. Fig. 8 gives the relation observed between temperature rise and relative watts loss, as drawn on log paper, for an exponent of 0.8. As a consequence of this variation in s, the time constant varies with the load on the transformer. Thus in Fig. 9 the first part of the curve, for 100 per cent load, during 19 hours, has $\tau_2 = 3.14$ hours, the ultimate temperature rise being 44.4 deg. cent. The second part of the curve, for 125 per cent load, during 11 hours, has $\tau_2 = 2.08$ hours, the ultimate additional temperature rise being 15.1 deg. cent., or 59.5 deg. cent. above ambient.

Fig. 10 gives a corresponding curve of temperature

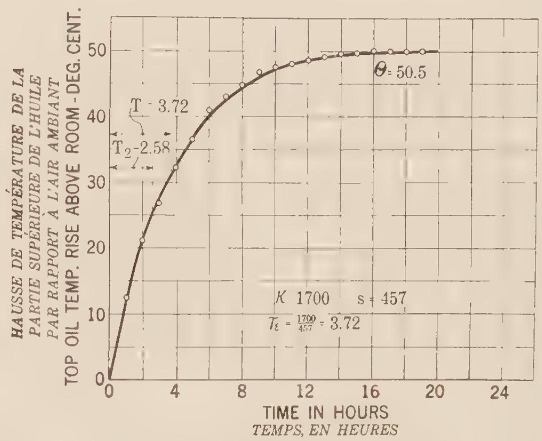

Fig. 10—Temperature Rise of Top Oil in a 2000-Kv-a. Air-Cooled, Oil-Immersed Transformer Starting Under Normal Load and Excitation from Ambient Room Temperature

Exponential curve computed to fit observations. (W. H. Cooney, Bibliography 18, Fig. 8).

rise in a 2-mv-a. air-cooled transformer, operated for 19 hours under normal load conditions. The thermal capacity is given as 1700 watt-hours per deg. cent., and the dissipation constant 457 watts per deg. cent., so

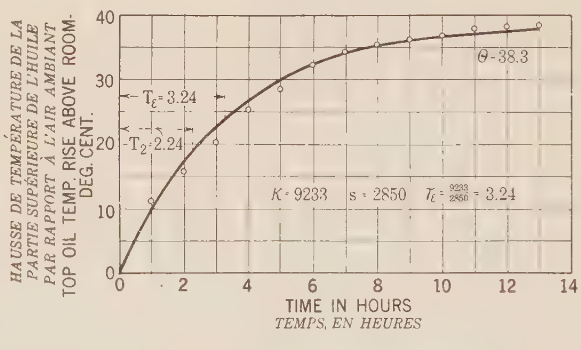

Fig. 11—Temperature Rise of Top Oil in a 12,500-Kv-a. Air-Cooled, Oil-Immersed Transformer, Starting Under Normal Load and Excitation from Ambient Room Temperature

Exponential curve computed to fit observations. (W. H. Cooney, Bibliography, Fig. 10).

that the exponential time constant τ_ϵ is 3.72 hours, and the binary time constant 2.58.

The curves in Fig. 11 refer to the case of a 12.5-mv-a. transformer, with a thermal capacity of 9233 watt hours per deg. cent.

In all of the cases represented in Fig. 9, 10 and 11 the time constants were computed from the dimensions and weights of the transformer elements. The exponen-

tial curves were then drawn according to these time constants so as to show the conformity or departure of the observed temperatures from the curves.

Conclusions

The cases presented in Figs. 4 to 11 indicate that various examples of different types of machines follow temperature rise exponential curves, under steady load, within limits of precision sufficient for many practical purposes. On the other hand, there are various machines which, either in whole or in certain elements, depart materially from such curves. It is, therefore, unsafe to assume that any or every machine, taken at random, will follow an exponential temperature rise curve, unless either a test or record of the machine will establish the fact.

The binary time constant of a machine in association with its ultimate temperature rise characteristic curve, will enable the thermal behavior of the machine to be predicted in the variable regime, under change of steady load.

It is desirable to study the temperature-rise curves of all classes of machines, in order to diffuse a general knowledge of their behavior in the variable regime, this being useful information for the operating engineer.

Appendix I

Montsinger-Cooney Method of Estimating Thermal Capacity of Air-cooled Oil-immersed Transformers

Data for thermal capacity of transformer from top-oil to exterior ambient temperature.

Sp. heat of copper wire 0.0935
Sp. heat of steel core 0.115
Sp. heat of oil 0.47

Spec. thermal capacity of copper wire 0.109 watt-hr./kg. and deg. cent.
Spec. thermal capacity of steel core 0.134 watt-hr./kg. and deg. cent.
Spec. thermal capacity of oil 0.462 watt-hr./liter per deg. cent.

The ratio of mean oil temperature to top-oil temperature varies with the form and size of the oil tanks, but an average value is 0.86. Applying this ratio, the mean specific thermal capacity of the tank oil is $0.462 \times 0.86 = 0.397$, or in round numbers 0.4 watt-hr./liter deg. cent.

The weight of steel core in a transformer is commonly about 5.5 times that of the copper wire. Applying this ratio to the total metal in the transformer, the average specific thermal capacity of that metal is

$$\frac{0.109 \times 1 + 0.134 \times 5.5}{6.5} = 0.13 \text{ watt-hr./kg. and}$$

deg. cent.

Different parts of the oil tank attain different temperature elevations. Experience shows that a ratio of $\frac{2}{3}$ may be applied to the weight of steel in the tank in estimating, its specific thermal capacity.

The thermal capacity of the entire transformer from the top oil to the external ambient temperature is then

$$k = 0.13 \text{ (kg. copper + kg. core + } \tfrac{2}{3} \text{ kg. tank)} + 0.4 \text{ (liters oil)} \quad \text{watt-hr. per deg. cent.}$$

Data for thermal capacity of winding with respect to top oil:

$$k' = 0.109 \frac{S + s'}{2\,S'} \times \text{kg. bare copper wire} \quad \text{watt-hr./deg. cent.}$$

where S is the cross-section of the insulated wire and s' is the cross-section of the bare wire

This formula for k' takes account of the specific heat of the insulation of the wire as well as that of the wire itself.

Example of Time-Constant Computation

Data for 100 per cent load and excitation.

Top-oil steady temperature elevation, 40 deg. cent.

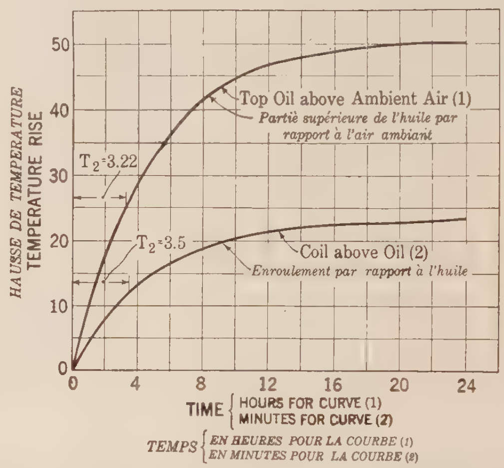

Fig. 12—Computed Temperature Elevation Time Curves for Transformer Having the Constants Analysed in Appendix I

Abscissas minutes for curve 2 coil rise above oil, and hours for curve 1 top oil above air

Winding steady temperature elevation, above top oil, 15 deg. cent.

Copper loss 9000 watts.
Core loss 6000 watts.

Weights, steel tank 2040 kg.
Steel core 1900 kg.
Copper 450 kg.

Volume of oil, 3410 liters.

Required the time constant for 125 per cent load and excitation, starting from ambient temperature.

Final copper loss $(1.25)^2 \times 9000 =$	14060 watts
" iron "	6000 "
Total, neglecting changes in resistance,	20060 watts

Θ_0 *for top oil.* Relative losses $\dfrac{20060}{15000} = 1.337$

From Fig. 1, oil rise $= 1.26 \times 40$ deg. cent. $= 50.4$ deg. cent.

$$k_2 = 0.13\,(450 + 1900 + 2 \times 2040/3) + 0.4 \times 3410 = 1850 \text{ watt hr./deg. cent.}$$

$$s_2 = 20060/50.4 = 398 \text{ watts/deg. cent.}$$

$$\tau_\epsilon = \frac{k_2}{s_2} = \frac{1850}{398} = 4.65 \text{ hours.}$$

$\tau_2 = 0.693 \times 4.65 = 3.22$ hours.

Θ for copper above top oil

$15 \times (1.25)^2 = 23.5$ deg. cent.

$k_\epsilon' = 454 \times 0.109 = 49.5$ watt-hr./deg. cent.

$s' = 14060/23.5 = 508.3$ watts/deg. cent.

$$\tau_\epsilon = \frac{k'}{s'} = \frac{49.5}{508.3} = 0.083 \text{ hour} = 5.0 \text{ min.}$$

$\tau_2 = 0.693 \times 0.0826 = 0.057$ hour $= 3.5$ min.

The exponential curves for θ_0 and θ_c are given in Fig. 12, as computed from the above data, together with their binary constants, to two different scales of time, as abscissas.

The original data from which Appendix I has been prepared, will be found in Bibliography 18 and 19.

Appendix II

FORMULA FOR DERIVING THE ULTIMATE TEMPERATURE RISE FROM AN INCOMPLETE TEMPERATURE RISE—TIME CURVE ASSUMED TO BE EXPONENTIAL.*

$$\Theta = \frac{\theta_1}{2 - (\theta_2/\theta_1)} \quad \text{deg. cent.}$$

where θ_1 is the temperature rise at the end of t_1 hours, and θ_2 is the corresponding temperature rise at the end of $t_2 = 2\,t_1$ hours. It is assumed that $\theta = 0$ at the start, and that the ambient temperature remains constant throughout.

Thus if $\theta_2 = 1.5\ \theta_1$, it will follow that $\Theta = 2\,\theta_1$ and $t_1 = \tau_2$.

FORMULA FOR COMPUTING THE BINARY TIME CONSTANT FROM TWO ORDINATES OF AN EXPONENTIAL TEMPERATURE RISE CURVE TAKEN AT TWO SUCCESSIVE EQUAL INTERVALS OF TIME FROM THE START.

$$\tau_2 = \frac{0.30103\ t_1}{\log\left(\dfrac{\theta_1}{\theta_2 - \theta_1}\right)} \quad \text{hours}$$

where θ_1 is the temperature rise after t_1 hours, and θ_2 the corresponding temperature rise after $t_2 = 2\,t_1$ hours. Thus if $\theta_2 = 1.5\ \theta_1 \qquad \tau_2 = t_1$

LIST OF SYMBOLS EMPLOYED

- ϵ = 2.71828 Napierian base.
- θ temp. rise above ambient (the latter assumed as constant) (deg. cent.)
- θ_1 temp. rise after time t_1 (deg. cent.)
- θ_2 temp. rise after time t_2 (deg. cent.)
- θ_a ambient temperature, (deg. cent.)
- Θ ultimate temp. rise above ambient, (deg. cent.)
- k thermal capacity of machine or element, (watt-hrs. per deg. cent.)
- s dissipation constant of machine or element (watts per deg. cent. rise above ambient).
- P output of a machine (watts)
- p power dissipated steadily in machine or element (watts)
- t time elapsed from start of temp. rise test (hours or mins.)
- τ_ϵ exponential time constant (hours or mins.)
- τ_2 binary time constant (hours or mins.)
- τ_{10} decimal time constant (hours or mins.)

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Without Pretensions as to Completeness

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Temperature Rise and Losses in Solid Structural Steel

Exposed to the Magnetic Fields from A-C. Conductors

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***Synopsis.**—Experimental investigations were made for the determination of the temperature rise and the losses occurring in structural steel members exposed to the fields from a-c. conductors. The work originated from the demand, among the designing engineers of an electrical manufacturing company, for practical data which would enable them to estimate, at least roughly, the temperature rise and the heat losses in the more common cases of structural steel members passing near the conductors. In the paper presented here, are given the results of the investigations in question. Examples are given illustrating the method of procedure in estimating temperature rise and losses in structural steel. The method of calculation applied is, in most cases, empirical. The major factors affecting temperature rise and losses are discussed on the basis of the test data. An understanding of these factors will often permit a designer to avoid iron heating without sacrifice of space or of economy. Thus a good part of the data presented applies to cases for which the temperature rise of the steel would ordinarily be considered not seriously objectionable.*

Introduction

In electric stations heavy a-c. conductors are often run in close proximity to steel structural members. It is well known that the steel members when exposed to a-c. magnetic fields will tend to heat on account of induced eddy currents and hysteresis losses. While a local temperature rise of a few degrees here and there in the steel will generally not be seriously objectionable, the iron losses must not reach an amount sufficient to raise materially the ambient temperature in the vicinity of the conductors themselves or in the vicinity of other electrical apparatus. Moreover undesirable expansion of the building steel and cracking of the concrete may sometimes result from excessive heating of the steel. It is even possible that, unless consideration is given to the iron losses, they may seriously add to the station losses.

While all of the above matters have been known, at least qualitatively, there has been but a scant amount of data available for designers to estimate the temperature rise and the losses in question.

Object and Scope of Paper

Since there has been an increasing demand for data on heating and losses in solid structural steel, especially in view of the more frequent use of the isolated-phase system of station layout, with its more wide-spread stray magnetic fields, an experimental investigation was made by an electrical manufacturing company to obtain, for their designers and engineers, practical data on the temperature and the losses in a number of the more common cases of structural steel members passing in the vicinity of heavy-current, a-c. conductors. Actual measurements of temperature rise and of losses on full-size steel members were made in the laboratory. Naturally only a limited variety of structural arrangements could be represented. Nor was it possible to set up a general or fundamental formula, for practical use, for the calculation of the temperature rise of solid iron members. Hence the application of

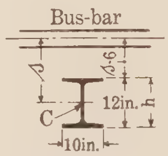

Fig. 1

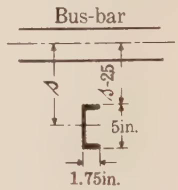

Fig. 2

Figs. 1-2—Test Positions of Iron Members (*I*-Beam and Channel Beam)

With respect to conductor crossing at right angles to the iron

the results obtained is primarily limited to the range of conditions covered by the tests. Nevertheless, it has been possible, by suitable choice of test conditions, to obtain a considerable amount of useful data, which

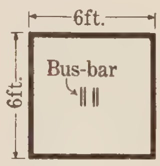

Fig. 3

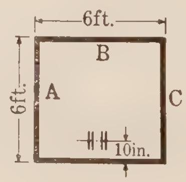

Fig. 4

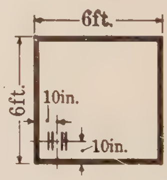

Fig. 5

Figs. 3, 4, 5—Test Arrangements of 6-ft. by 6-ft. Closed Channel Iron Frame

With respect to a straight conductor passing through the frame at right angles to its plane

have been effectively applied for a year or more, in practical cases of station steel design and of conductor layout. The principal results obtained are summarized in the following paper. No recommendations are made, however, concerning the safe permissible temperature rise of the steel members or the maximum allowable losses.

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Abridgment of paper presented at the Midwinter Convention of the A. I. E. E., New York, N. Y., February 8-11, 1926. Complete copies available upon request.

Method of Test

The iron structural members to be tested—in most cases full-size pieces—were placed in a variety of positions with respect to heavy-current test circuits. In a good many of the tests, isolated-phase construction was simulated by having the return conductors relatively remote from the samples under test, so that the simple case of one infinitely long, straight conductor, with the return conductor infinitely remote, was closely approached. In other tests, the resultant field at the iron member under test, due to all conductors in the circuit, had to be considered. Moreover, in some circuit arrangements the adjacent-phase construction was deliberately imitated. The effects of conductor bends and loops on nearby iron members was also investigated. All tests were made at an ambient temperature of from 20 to 25 deg. cent.

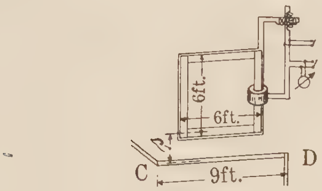

Fig. 6—Test Arrangement of "Electric Loop" Consisting of a 6-ft. by 6-ft. Channel Iron Frame

Conductor *C D* being in the plane of the frame

For the I-beam, channel beam, switchboard pipe, round reinforcing rods and steel plates tested the resistivity ranged from 13.2 to 15.9 microhm-cm., and the maximum permeability from 1210 to 1800 at densities of from 6200 to 7800 gausses. In so far as structural steel members are concerned (having values of resistivity and permeability within the range of those given) approximate estimates of temperature rise may therefore be made on the basis of the test data given here (in accordance with the procedure outlined in the examples below), without further consideration of permeability and resistivity.

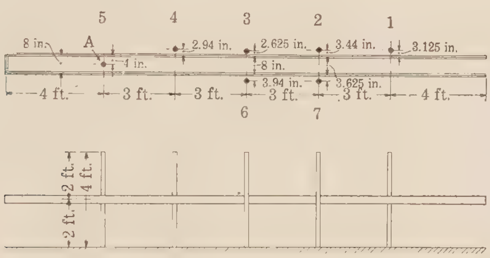

Fig. 7—Conductor and Iron Pipe Layout in Iron Heating Tests

With pipes passing outside of conductor group as well as between going and return conductors in adjacent-phase circuit

The temperature measurements were made with mercury thermometers attached with putty to the iron samples under test, or by thermocouples in the case of some of the smaller samples such as reinforcing rods. In most cases the sustained final temperatures, or temperature rise, of the steel for constant loads were obtained.

The currents in the test circuit were of substantially sine-wave shape at frequencies of either 60, 40 or 25 cycles per sec. and were as high as 5800 r. m. s. amperes.

In a number of cases loss measurements were made. The method was to obtain the total input into the busbar system and to subtract therefrom the copper losses. A sensitive wattmeter of the reflecting dynamometer type was used whose current coil was connected to the line-current transformer and whose potential circuit was connected to two points of the busbar system embracing all the flux which produces losses. The copper losses were measured separately in the absence of the iron members. The measurement of a known loss (of the order of magnitude of the iron losses) produced

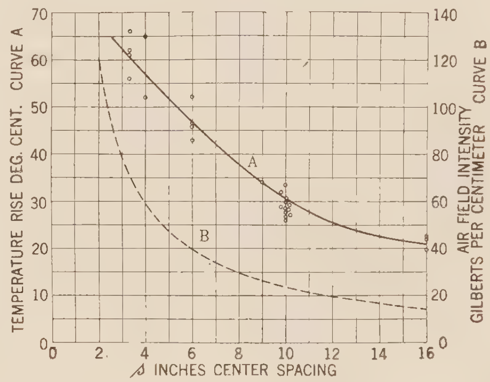

Fig. 8—Temperature Rise vs. Spacing (Curve A)

For long straight bare structural iron members crossing at right angles to a straight 3000-ampere, 60-cycle conductor, return conductors remote

Curve A: Final maximum temperature rise at iron hot spot for a constant conductor current

Curve B: Air field intensity vs. spacing for a single 3000-ampere straight long conductor

Center spacing measured from center of conductor to center of iron member

by a current induced in a short-circuited coil by the flux from the busbar circuit showed an over-all accuracy of loss measurements of better than 10 per cent.

Short-circuited copper windings of one or more turns were placed around the iron member in several cases so as to embrace the flux passing through the iron member and thus to reduce the iron loss. Measurements of the circulating current in the short-circuit windings were made for the purpose of obtaining a relation between iron heating (and losses) and the ampere turns in the short-circuited copper.

RESULTS OF TESTS

I. Straight Magnetic Members

Effect of Current on Temperature Rise

The final temperature rise at the surface of the steel member at the point nearest to the conductor, was found to vary as the 1.7th power (average value) of the conductor current for thick steel members (thicker than, say 1/8 in.) crossing at right angles to a conductor. The

value given is an average exponent derived from test results covering a current range from 1000 to 5800 amperes, center spacings between conductor and iron member from 2.5 to 16 in., and values of iron temperature rise from 10 to 175 deg. cent. Values of the exponent obtained from the various tests ranged from as high as 2 (for low values of maximum flux density and temperature rise) to 1.4 (for the highest values of temperature rise tested).

Temperature Rise at Different Spacings for Straight Iron Member Crossing at Right Angles to a Single Straight Conductor

The effect on temperature rise of spacing alone, in the absence of material effects of return conductors, is indicated in Fig. 8, for the case of a long, straight 3000-ampere, 60-cycle conductor crossing at right angles to a long, straight, horizontal, bare, solid, structural iron member. (It will be shown later that the shape and size of the iron member within certain limits, do not materially affect the hot-spot temperature rise for a given center spacing and current). All spacings are from center of conductor to the center of the iron member.

According to Fig. 8 it is seen that increasing the spacing from 6 to 10 in. reduced the maximum temperature rise of the iron 35 per cent, a further increase of spacing to a total of 16 in. gave a temperature rise about half that for the 6-in. spacing.

Effect of Frequency on Temperature Rise

Tests for temperature rise at 25, 40 and 60 cycles per sec. gave values of temperature rise roughly in the ratio of 1, 1.3, and 1.6, currents and center spacings being the same. The tests were made on 1¼-in. standard switchboard bare iron pipes and on bare ½-in. round and ½-in. square iron reinforcing rods.

Effects of Size, Shape, and Thickness on Temperature Rise

Various kinds of straight iron members crossing at right angles to a conductor, and not less than, say ⅛ in. thick and of cross-sectional dimensions (in a direction perpendicular to the conductor as dimension h in Fig. 1) up to 12 in. at *center spacings* from 10 in. to 16 in. from the conductor, had substantially equal values of temperature rise at any given busbar current, as indicated by tests of the following iron members: 12-in. by 10-in. I-beam, 5-in. by 1¾-in. channel beam, 4-in. by ⅜-in. by 8-ft. steel plate, 10-in. *I*-beam flange,* 1¼-in. switchboard steel pipe. See Fig. 9. In other words, the temperature rise under these conditions was *independent of the size, or cross-sectional area or shape for a given center spacing between conductor and iron,* regardless of the distance from the conductor to the nearest part of the iron. Variations of temperature rise within this rule were found to be not higher than 30 per cent and usually much less.

*Cut from the 12 in. I-beam already mentioned.

If the iron members have a thickness of the order of, or less than, two or three times the equivalent depth of flux penetration* (calculated for relatively thick members), or say less than ⅛ in., it will have a smaller temperature rise than thicker iron members because a smaller volume of iron per unit of surface will participate in the production of loss as indicated in Fig. 9.

Effect of Fields from Several Conductors on Temperature Rise of Iron

In a great many practical cases, there is more than one conductor contributing to the field at the hot spot of the iron. A number of such cases were tested and the following approximate rulings for iron heating were obtained when the "air-field intensity" along the axis of the iron member was taken into account. By "air field intensity" is meant the calculated resultant intensity, due to all conductors, in air assuming no magnetic bodies present, the intensity for the present

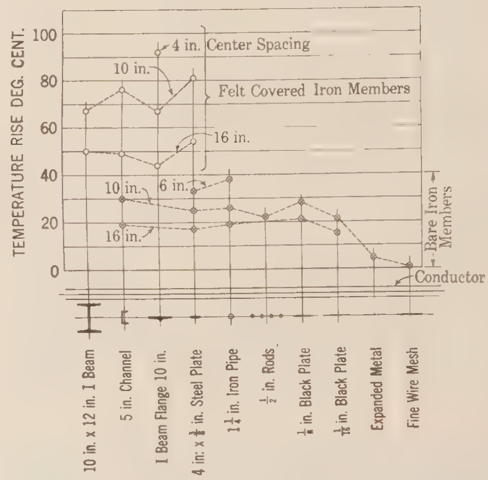

Fig. 9—Comparison of Values of Maximum Temperature Rise

For different iron members crossing at right angles to conductor
Iron members horizontal
Constant busbar current of 3000-amperes at 40 cycles per sec.
Figures on plot indicate center spacing between conductor and iron members

purpose being calculated along the line of the longitudinal center axis of the iron member at the section through the hot spot, *i. e.*, usually at the point where the axis is at the shortest distance from the nearest conductor. The relations pertaining to the effects of the magnetic fields from several conductors on temperature rise in solid iron are:

a. At any given center spacing from iron member to nearest conductor, the hot-spot temperature rise varied as the 1.4 to the 2.0 power (see Table I) of the air field intensity calculated for the center point of the cross section nearest to the conductor, as for instance, point C in Fig. 1—a relation similar to that already given for the current.

*Bibliography 2.

TABLE I

VALUES OF EXPONENT n, IN EQUATION (1) FOR CALCULATION OF TEMPERATURE RISE OF SOLID STRUCTURAL IRON MEMBERS CROSSING AT RIGHT ANGLES TO CONDUCTORS

H r. m. s. gilberts per cm. air field intensity.	n
20 or less	2.0
50	1.7
100	1.5
150	1.4

b. An approximate relation useful in a variety of cases for estimating the temperature rise of iron members exposed to fields from more than one conductor was found to be the following: at any given center spacing between an iron member and the conductor contributing the major component of the resultant field (usually this is the conductor passing nearest to the iron) the maximum hot-spot temperature rise, for any particular value of air field intensity (due to all conductors), at the center of the iron section through the hot spot, was independent of the arrangement of conductors—within certain limits.

A material departure from rule (b) was found, as would be expected, for those cases in which the different arrangements of conductors involved considerable changes in the distribution of the m. m. f. along the iron member (*i. e.,* on either side of the hot spot.) Thus for iron members outside the loop of Fig. 7, such as pipes No. 3 and 6, the experimental values of temperature rise were from 20 to 30 per cent less than those estimated from rulings *a* and *b* above, the reduction allowing for the fact that in the cases in question the m. m. f. and hence the iron losses fall off much more rapidly along the iron (*i. e.,* on one or on both sides of the hot spot) than the m. m. f. and the losses in a steel member crossing at right angles to *one* straight conductor only, center spacings being equal.

IRON MEMBERS RUNNING PARALLEL TO CONDUCTOR

A long and narrow steel member, such as an I-beam, a channel, or a pipe, will ordinarily heat much less (from 30-80 per cent less in the cases tested) when running parallel to the conductor than when crossing it at right angles, for the same spacings and currents. This is because the iron portion of the flux path around the conductor is a much smaller part of the complete flux path than in the case of a steel member crossing at right angles to the conductor. It will, therefore, often be advantageous from the standpoint of iron heating to lay out stations with the conductors parallel rather than at right angles to the iron members.

LOSSES IN STRAIGHT IRON MEMBERS CROSSING AT RIGHT ANGLES TO CONDUCTORS

A few loss measurements were made to indicate their general order of magnitude in a few cases, and their relation to the current magnitude, frequency, to the cross-sectional dimensions of the solid iron members, and to the spacing between iron and conductor. A complete investigation of losses to cover the wide field of the many customary structural layouts was, however, not made.

EFFECT OF FREQUENCY ON LOSSES

The relation between frequency and total loss in iron was investigated in the case of a closed iron ring 4-in. wide, ¼-in. thick and 20-in. average diameter. The results of the loss measurements, at 25, 40 and 60 cycles per sec., show that the loss varied roughly as the square root of the frequency.

EFFECT OF CURRENT ON LOSSES

Loss measurements at currents ranging from 1500 to 3000 amperes were made for a 10-in. by 12-in. steel I-beam, a 5-in. by 1¾-in. channel, a 4-in. by ⅜-in. steel plate, and a 1¼-in. standard switchboard iron pipe, when passing at right angles to a straight

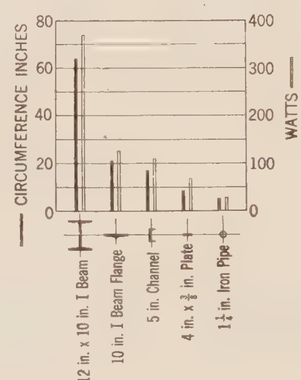

FIG. 10—COMPARISON OF TOTAL IRON LOSS WITH CROSS-SECTIONAL PERIMETER OF VARIOUS IRON MEMBERS CROSSING AT RIGHT ANGLES TO CONDUCTOR

Each iron member was tested separately
Center spacing between iron member and conductor 10 in.
Test current 3000 amperes at 40 cycles per sec.

conductor. The losses for the I-beam varied as the 1.8 to 1.9 power of the current, at constant spacing from the conductor. For other samples tested, this exponent was as low as 1.6

EFFECTS, ON LOSSES, OF CROSS-SECTIONAL AREA CIRCUMFERENCE AND SHAPE OF SOLID IRON MEMBERS

For iron members crossing at right angles to a conductor and not less than ⅛ inch thick and of cross-sectional dimensions (in a direction perpendicular to the conductor such as dimension h in Fig. 1) up to 12 in, at any given center spacing within the range from 6 to 16 in., the iron losses at any given current were actually found by test (see Figs. 10 and 11) to vary only with the circumference of the iron section and not with its area for the following iron members tested: 12-in. by 10-in. I-beam, 5-in. channel iron, 1¼-in. iron pipe, 4-in. by ⅜-in. steel plate, 10-in. I-beam flange.* Moreover, at any given spacing and conductor current, the loss for these iron members when crossing at right angles to a conductor was approximately proportional

to the circumference of the iron cross section, as indicated in Figs. 10 and 11. Deviations from this rule were less than 30 per cent (based on the average of the measured values) for the iron members tested. This result is in good agreement with the behavior of solid iron plates in respect to flux penetration and eddy-current loss, as worked out by previous investigators.†

Effect of Spacing

The relation between loss and spacing for straight iron members crossing at right angles to a straight conductor is indicated in Fig. 11. The curves show the average total measured loss per inch length of cross-sectional perimeter for center-spacings from 4 in. to

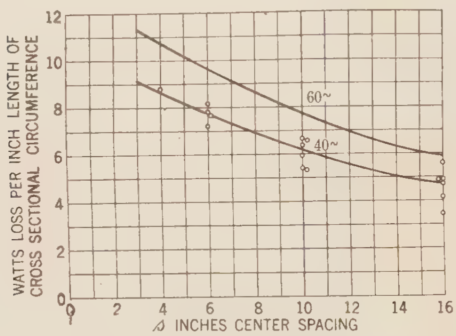

Fig. 11—Iron Loss per Inch Length of Iron Cross-Sectional Perimeter vs. Spacing

Test circuit closely approaching, as far as iron heating and losses are concerned, the arrangement of a single, long, straight conductor crossing at right angles to a straight long iron member. Busbar current 3000 amperes Center spacing *s* measured from center of conductor to center of iron member

16 in. from a 3000-ampere conductor at 40 cycles and at 60 cycles.

II. Closed Iron Loops Around Conductor

Temperature Rise

To simulate *large frames of structural steel,* the circuit arrangements of Figs. 3, 4 and 5, with a 6-ft. by 6-ft. square frame of four 5-in. by 1¾-in. structural channel irons riveted or bolted together at the corners, were tested at busbar currents ranging from 1500 to 3000 amperes. The results of these tests showed that the temperature rise of iron beams in *large* rectangular magnetic frames surrounding a straight conductor and having sides larger than, say, 5 ft. may be calculated separately for each individual beam disregarding the other three sides of the frame, even if the conductor passes near the corner at a point as close as 8 in. from the nearest part of each of the two adjacent sides.

Small Frames. Both calculations and experimental observations indicate that small, closed uniform magnetic frames having sides of the order of, say, 2 ft. or less when surrounding a conductor must be expected to heat considerably more than a single straight iron member passing at right angles to a conductor, for equal spacings.

Ducts of Iron Enclosing a Straight Conductor

In order to demonstrate experimentally that relatively high values of temperature rise and of loss may be obtained for sheet iron ducts completely enclosing an a-c. conductor, a horizontal 18-in. by 18-in. square iron duct of annealed iron sheets ⅛ in. thick was tested and gave a maximum temperature rise of 78 deg. cent. at the iron for a 3000-ampere, 40-cycle‡ busbar current, and an iron loss of 600 watts per foot of duct length.

Replacing the two horizontal iron sheets of the duct by non-magnetic sheets, but retaining the two iron side sheets, reduced the maximum temperature rise of the iron to 20 per cent; the total iron loss was reduced to about 10 per cent.

III. Closed Iron Frames Parallel to Conductor

The circulating current in a 6-ft. by 6-ft. channel iron frame as shown in Fig. 6 was of the order of 100 amperes when a straight 3000-ampere conductor was run parallel to one side of the frame and at 10 inches center spacing from the nearest channel iron, the conductor being outside the frame but in the same plane with it. The temperature rise of the iron was negligible. While the observed current in the 6-ft. by 6-ft. frame was small, considerably larger currents of, say, several hundred amperes may flow in heavy structural-iron frames of isolated-phase stations when the iron loops are large (say 15 or 20 ft. on a side) and especially when a heavy-current bus follows two sides of the frame§ or when the flux linking the iron loop is materially increased by the effects of other conductors. However, on account of the large surface over which the losses due to circulating currents in closed frames of large structural beams are distributed, their temperature rise will commonly be of minor consequence.

Copper Short-Circuit Rings

To Reduce Heating in Magnetic Members Crossing at Right Angles to Conductor. Copper loops around iron members crossing at right angles to heavy-current conductors may be used effectively to reduce the losses and temperature rise of the iron members; but when

*Cut from the 12-in. I-beam already mentioned.

†Bibliography, 2, 5, 7.

‡60-cycle values of temperature rise and losses approximately 20-30 per cent higher.

§The circulating currents may be estimated for the more common types of frames if the magnitudes and relative phases of the currents in the nearby conductors, the dimensions of the frame and its position with respect to the conductors are known. The calculation in question involves determining the mutual inductance between the frame and the conductors, the self inductance and the skin-effect resistance of the frame. For skin-effect resistance calculations the reader is referred to Bibliography 2. From the loss, determined by the circulating current and the effective frame resistance, the order of magnitude of the temperature may be obtained from loss vs. temperature rise relations such as those given in Bibliography 12.

designed with too small a current-carrying capacity the copper loops may themselves seriously overheat.

In two typical cases, one with an iron girder beam 10 in. by 12 in., another with a 1¼-in. iron pipe, a copper sleeve or short-circuit winding having an ampere-turn capacity of 30 per cent of the busbar current reduced the iron losses and temperature rise to less than 10 per cent of their original values. In both cases the center spacing between the busbar and the iron member (crossing at right angles to the busbar) was of the order of from 6 to 10 inches, the busbar current ranging from 1500 to 3000 amperes.

Examples

Example 1. Estimate the hot-spot temperature rise of a square, vertical, bare channel-iron frame, having 6-ft. sides consisting of 5-in. by 1¾-in. bare channels, when a 3000 ampere, 60-cycle conductor passes at right angles through the plane of the frame at a point 10 in. above the center of the lower horizontal channel (Fig. 4), the frame being placed so that the channel section through the hot-spot is located as shown in Fig. 2 with respect to the conductor, s being 10 inches.

In estimating the hot-spot temperature rise it will be remembered that in large frames of this kind the maximum temperature is not affected by the presence of the three channel iron sides A B C; in other words the hot-spot temperature rise may be estimated by following the procedure given for single straight iron members.

Accordingly the first step is to obtain the reference temperature rise $T\,R_r$ from Fig. 8 for a straight horizontal iron member crossing at 10-in. center spacing from a long, straight 3000-ampere, 60-cycle conductor. Thus

$$T\,R_r = 31 \text{ deg. cent.}$$

and

$$H_r = 23.6 \text{ gilberts per cm.}$$

Calculating H, the air field intensity for s = 10 in. at the center of the channel section through the hot spot, the value

$$H = 24.8 \text{ gilberts per cm.}$$

is obtained, the excess of H over H_r being due to the effects of the return conductors in the circuit in question. Then the hot-spot temperature rise in the channel is found from*

$$\frac{T\,R}{T\,R_r} = \left(\frac{H}{H_r}\right)^n \qquad (1)$$

Where n in this case is 1.85, interpolated from Table I. Substituting the values

$$T\,R = 31\left(\frac{24.8}{23.6}\right)^{1.86} = 31 \times 1.095$$

Hence

$$T\,R = 34 \text{ deg. cent.}$$

*Based on relations (a) and (b) established above under the heading "Effect of Fields from Several Conductors on Temperature Rise of Iron."

i e., the desired final hot-spot temperature rise for a constant 3000-ampere current is estimated to be 34 deg. cent.

The nearest test condition to compare with this calculated result is a 40-cycle, 3000-ampere test with the frame of Fig. 4 and the same circuit, which test gave a 40-cycle, hot-spot temperature rise of 29.5 deg. cent. by thermometer. Estimating from the calculated 60-cycle temperature rise of 34 deg. cent., the corresponding 40-cycle temperature rise by the relation:

$$\frac{T\,R \text{ at 40 cycles}}{T\,R \text{ at 60 cycles}} = \frac{1.3}{1.6}$$

a 40-cycle value of $\dfrac{34}{1.23}$ = 28 deg. cent. is calculated, which is in good agreement with the test value of 29.5 deg. cent.

Example 2. Estimate the loss in a structural 12-in. by 10-in. I-beam placed as shown in Fig. 1 with respect to a long straight conductor crossing at right angles to the beam. Let

s = 16 in.
I = 2600 amperes
f = 60 cycles per sec.
P = 64 in.

From Fig. 11, at s = 16 in.

L_0 = 5.9 watts per inch length of perimeter for a 3000-ampere reference current. Then the total loss at I = 2600 amperes is estimated from

$$L = P\,L_0\left(\frac{I}{I_r}\right)^n \qquad (2)$$

where n = 1.75, an average value. Hence

$$L = 64 \times 5.9 \times \left(\frac{2600}{3000}\right)^{1.78} = 295 \text{ watts}$$

Thus the total loss in the I-beam is estimated at 295 watts. The loss measured at 40 cycles per sec. with 2600 amperes was 230 watts, which is in good agreement with the estimated 40-cycle value of $\dfrac{295}{1.25}$ = 235 watts.

Symbols

f frequency, cycles per sec.

H r. m. s. gilberts per cm. in air, resultant air field intensity, due to all conductors, in the absence of iron members, calculated at the point occupied by the center of the iron cross section through the hot spot and in the direction of the longitudinal axis of the iron.

H_r r. m. s. gilberts per cm. reference air field intensity at spacing s inches from a long straight 3000-ampere conductor.

I r. m. s. amperes, conductor current for which iron heating or losses are desired.

I_r r. m. s. amperes, reference current of 3000 amperes flowing in a long straight conductor.
L watts total loss in solid iron member.
L_0 watts loss per inch length of perimeter P, for reference current I_r and spacing s.
n exponent of current or of air field intensity in temperature-rise calculations by equations (**1**) or (**2**).
ω $= 2\pi f$.
P inches perimeter of cross section of solid iron member.
ρ ohm-cm. resistivity of solid iron.
s inches, center spacing between iron member and nearby conductor.
$T R$ deg. cent. hot-spot temperature rise at solid iron for current I and spacing s.
$T R_r$ deg. cent. reference temperature rise at spacing s for current I_r.

Summary

1. Results are given of measurements of temperature rise and of losses in structural steel I-beams, channels, pipes, plates, ducts and of temperature rise in rods, sheets and meshes when the iron members were exposed to the fields from 60-cycle, 40-cycle or 25-cycle conductors carrying currents as high as 5800 amperes. Experimental data were obtained to serve as a basis for designing copper sleeves to minimize heating and losses in structural-iron members crossing at right angles to conductors. Special tests were made on riveted and bolted steel frames placed within the field from a high-current circuit simulating isolated-phase construction. Empirical data and a simple procedure are given in the paper for estimating the temperature rise of straight steel members exposed to the magnetic fields from more than one conductor.

2. Iron members passing between going and return conductors in adjacent-phase layouts may reach very high temperatures; on the other hand, iron members passing at right angles to but outside of a group of going and return conductors will usually heat less than an iron member crossing a single conductor, when the current and minimum spacings are the same.

3. The temperature rise of structural iron beams in large rectangular magnetic frames surrounding a straight conductor (as in isolated-phase layouts) and having sides larger than, say, 5 ft. may be calculated separately for each individual beam disregarding the other three sides of the frame, even if the conductor passes near the corner at a point as close as 8 in. from the nearest part of each of the two adjacent sides. Small closed structural steel frames or ducts having sides of the order of two ft. or less, when surrounding a conductor, must however be expected to heat considerably more than a single straight iron member passing at right angles to a conductor, for equal spacings and currents.

4. A long and narrow steel member, such as an I-beam or a channel, will ordinarily heat much less when running parallel to a conductor than when crossing it at right angles, for the same spacings and currents. This is because in the parallel arrangement the iron portion of the flux path around the conductor is usually a much smaller part of the complete flux path than in the case of a steel member crossing at right angles to the conductor. It will, therefore, often be advantageous, from the standpoint of iron heating, to lay out stations with conductors parallel rather than at right angles to the iron members.

5. For various sizes of straight long solid structural iron members crossing ar right angles to a conductor and having a thickness not less than ⅛ in., when placed with respect to the conductor at any one center spacing within the range from, say, 6 to 16 in., the temperature rise was practically independent of the size, or cross-sectional area or shape of the iron member. In the same tests the losses of the various solid structural iron members not thinner than ⅛ in. were proportional to the perimeter of the iron cross section regardless of shape or volume. The iron members in question ranged in size from a 1¼ in. standard pipe to a 12 in. by 10 in. I-beam.

6. The values of temperature rise of structural iron members at the frequencies of 25, 40 and 60 cycles per sec. were roughly in the ratio of 1:1.3:1.6; *i.e.*, the 60-cycle temperature rise was 60 per cent higher than that at 25 cycles per sec.

7. The circulating current in a 6-ft. by 6-ft. channel iron frame was of the order of 100 amperes when a straight 3000-ampere conductor was run parallel to one side of the frame and at 10 inches center spacing from the nearest channel iron, the conductor being outside the frame but in the same plane with it. The temperature rise of the iron was negligible. While the observed current in the 6-ft. by 6-ft. frame was small, considerably larger currents of, say, several hundred amperes may flow in heavy structural-iron frames of isolated-phase stations when the iron loops are large (say 15 or 20 ft. on a side) and especially when a heavy-current bus follows two sides of the frame or when the flux linking the iron loop is materially increased by the effects of other conductors.

8. Short-circuited copper loops or bands around iron members crossing at right angles to heavy-current conductors may be effectively used to reduce the losses and temperature rise of the iron; but when designed with too small a current-carrying capacity, the copper loops themselves may seriously overheat. In two typical cases a copper sleeve, or short-circuit winding, having an ampere-turn capacity of 30 per cent of the busbar current reduced the iron losses and temperature rise to less than 10 per cent of their original values.

Acknowledgment. The authors are indebted to Mr. D. Basch for the use of iron-heating data obtained under his direction in a number of the earlier tests.

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NEW DISCOVERY MAY BROADEN ELECTRIC TRUCK FIELD

The recent discovery of a new element making possible much lighter storage batteries, as reported late in March from Vienna, Austria, will, when perfected for commercial use, broaden the transportation field now served by the storage battery truck. It is said that the new element is one-fifth the weight of lead and surpasses the lead accumulators now used in storage batteries in both capacity and power. That electricity is playing an important role in transportation is evidenced by the many installations of the electric truck for industrial plant hauling and city delivery service.

THE LONGITUDINAL FORCE IN CONDUCTORS

By Carl Hering

The existence of a mechanical force in the direction of the axis of a conductor, the recognition of which the writer has been urging for many years, has been strenuously opposed by many (chiefly teachers and book writers) because it does not fit in with Maxwell's mathematical system, which recognizes only perpendicular forces. No one, however, has shown that it does not nor cannot exist, and it seems that its acceptance is now gaining, though slowly.

The following seems to convince opponents better than the writer's numerous other experimental proofs.* A loop of very flexible wire laid irregularly on a table, or floated on mercury, when insulated from it, will expand into a circle (or into a figure 8) when a strong current flows through it. The radial pressure of the flux inside of the loop is then balanced by a tensional force in the wire, quite analogously to these forces in a soap bubble or a toy balloon. This is the much disputed longitudinal or stretching force. This (as well as the radial force) is due to the mutual repulsion of the flux lines around the wire, and is an internal force or stress, due to its own flux; it should be carefully distinguished from the forces due to the flux from external circuits. Neither Maxwell nor Ampere seem to have known of the existence of any internal forces.

In the single, straight, conductor (one which is far removed from all others) the writer computed this force to be $i^2/200$ dynes, in which i is in amperes; hence it is very small. If certain newer theories are correct, it would follow that with 100 amperes in a single-turn circular circuit of 40 cm. diameter and 6 mm. diameter of wire, this force ought to be roughly about one gram, hence considerably greater, and the product of this force by the circumference of the circle, ought to be equal to the stored energy. This is a deduction and remains to be checked by tests, as this force has, apparently, never been measured before.

To enable passengers to see scenery at night, the Chicago Milwaukee and St. Paul Railway will, it is understood equip all observation cars on transcontinental trains with powerful adjustable floodlights.

Some 45 patents are said to be pending on a new process of taking and showing stereoscopic ("3-dimensional") moving pictures. A minimum screen width of 38 feet is required.

A blue glass recently concocted at the United States Bureau of Standards has the property of furnishing protection against ultra-violet rays. About half the lime in a soft soda-lime glass is replaced with cerium oxide, and sufficient cobalt oxide added to produce the desired color.

*Trans. A. I. E. E., Vol. 42, 1923, p. 321.

Tests of Paper-Insulated High-Tension Cable

BY F. M. FARMER[1]

Fellow, A. I. E. E.

Synopsis.—*The paper deals with those tests which are involved in specifications. The discussion is from the standpoint of the purpose and significance of the various standard tests which are made rather than that of the technic of the details of testing. A considerable number of data are given.*

The subjects treated are purpose and importance of tests of cable; insulation resistance test; high voltage test; dielectric loss and power factor test; "ionization" test; bending test; accelerated life test; preparation of samples for high-voltage tests and tests of components.

The possible significance of wide variation in some of the properties of cable is discussed. The relation found between time and voltage based on a large number of tests of both three conductor and single conductor cable is discussed at considerable length. A test for stability of the impregnating compound is described as is also a proposed standard load for dielectric-loss testing. Some data are given showing the effect of repeated bending on lead and how that effect is influenced by the tensile stress in the lead.

The paper concludes with a list of the ways by which, in the author's opinion, progress can be made in the improvement of the quality and the design of paper-insulated high-tension cable.

* * * * *

Introduction

Tests which are made on paper-insulated, high-tension cable may be divided into the three following general classes:

a. Research tests for the ultimate purpose of advancing this branch of the electrical industry by means of improvements in quality of materials and manufacturing processes, or improvements in cable design.

b. Tests on the commercial product at the factory to determine compliance with the manufacturer's standards or the purchaser's specifications.

c. Tests on cable after it is installed, including acceptance tests on new cable, periodic tests and fault location tests.

It is not feasible to cover even superficially all of these tests within the limits of one paper. It is, therefore, proposed principally to discuss those standard tests which are involved with specifications and certain other tests which, while not yet in specifications, aid in determining the quality of cable and the improvements which have been made therein. Furthermore, it is not proposed to discuss to any great extent the details of the technique of testing cable, but rather the purpose and significance of tests.

Purpose and Importance of Tests of Cable

Ostensibly tests in connection with the purchase and acceptance of cable are made for the purpose of determining whether or not the material complies with the specified requirements. The basic object, however, is to determine the suitability of the cable for the service to which it is to be applied. The specifications are, in effect, simply the engineer's method of describing cable which it is believed will be suitable for that service.

In no class of electrical apparatus does more reliance have to be placed on tests to determine suitability than in the case of cables. Insulation is a more or less important feature in all electrical apparatus but in high-tension cables it is *the* factor. The insulation in a high-tension transformer for example is, of course, of prime importance but the amount involved in the largest unit is insignificant compared to that in a cable line of average length. Consider for instance, the 66-kv. line of the Cleveland Electric Illuminating Company which consists of two three-phase circuits of three, single-conductor cables each. This line is about eight miles long and contains, therefore, about 50 miles of cable. The mean area of the insulation of this cable is about 123,000-sq. ft. or a little over 2.8 acres. While a few hundred sq. ft. of insulation are continuously under stress in the transformers at each end of this line there are nearly three acres of insulation buried in the ground, every square inch of which is expected to withstand continuously all day and every day a potential of 38 kilovolts.

Unfortunately we know far less about insulation than about any of the other essential classes of materials in electrical apparatus. In the case of cables, we impose particularly severe conditions because we effectually cover the insulation with a sheathing of lead so that no visual inspection whatever is possible and the sins of omission and commission, are thoroughly buried. We must, therefore, determine the suitability of this important part of a cable very largely by tests. Perhaps a better way of putting it would be to say that the best we can do is to make certain tests with the hope that, in the light of our present knowledge, they will eliminate cable which would be unsuitable for the intended service as prescribed by the specifications.

Insulation Resistance Test

The test for insulation resistance is one of the earliest made on electrical conductors. In the early days of the art when only low voltages were involved it served very satisfactorily as a means of detecting sections of wire or cable which would be likely to prove unsatisfactory in service. At such low voltages the inherent quality of the insulation did not have to be of a very high order and the principal things to be guarded against were mechanical defects and accidental injuries. The insulation

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Abridgment of paper to be presented at the Regional Meeting of the A. I. E. E., District No. 5, Madison, Wis., May 6-7, 1926. Complete copies available upon request.

resistance test served very well in weeding out wire or cable defective from these causes.

With the advent of higher voltages it was found that insulation resistance tests were of very limited usefulness in determining the inherent value of the insulation and that other tests were much more important in insuring a satisfactory product. It is now generally recognized that the number of megohm miles of a cable has little significance and no one can predict that a cable with high-insulation resistance will give better service than one with low resistance or vice versa.

While the actual value of the insulation resistance in megohm miles may not be significant, the *variation* in

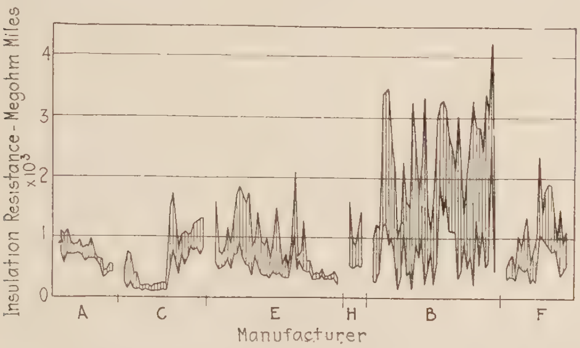


Fig. 1—Insulation Resistance of 13-15-Kv. Cable Inspected During 1925

Upper line, maximum insulation resistance in each lot inspected
Lower line, corresponding minimum insulation resistance

the megohm miles between different sections of the same cable line, which are supposed to be identical in quality, may be very significant. The variation in the quality of high-tension cable is one of the greatest problems in the cable art for it is the weakest link in the chain that determines its strength and the problem of producing cable which is uniform from section to section or even foot to foot has yet to be solved. Obviously, cable having the least variation in quality is better than one the quality of which, although it may have a higher average value, varies over a wider range.

Fig. 1 has been prepared from insulation resistance measurements made in the course of the routine inspection of high-tension cable at six factories during 1925. The upper heavy line connects the values of maximum resistance found in each lot of cable and the lower heavy line connects minimum resistances. Each light vertical line connects the maximum and minimum values of resistance found in each lot submitted. The shorter the light vertical line is, the smaller is the variation in a single lot. The smoother the heavy lines are, the smaller is the variation between lots. It is evident that make "B" takes first place for variation while make "A" is conspicuously uniform, with "C" a close second.

Just what the practical significance of these differences in uniformity of insulation resistance is, we do not know. With respect to quality of the cable, these differences may mean much or they may mean little but it is submitted that until we have some means of measuring the quality of insulation more directly, we are justified in concluding that other things being equal, the cable with the smaller variation is the better.

High-Voltage Tests

High-voltage tests of various kinds have long been considered the most important of all that are made on high-tension cable. They may be classified into (a) fixed or stated voltage tests, (b) momentary breakdown voltage tests and (c) time breakdown voltage tests.

(*a*) *Fixed Voltage Tests.* A fixed voltage test consists in the application of a prescribed voltage for a prescribed length of time to each reel of cable in the case of acceptance tests at the factory, or to an entire line of cable in the case of installed cable.

Volumes on the discussion of this subject of fixed voltage tests of insulation for all purposes, and cable in particular, have been printed. How high should the test voltage be and how long should it be applied to insure that the cable meets the desired standard without injuring the insulation? Which is the more effective, high voltage for a short time or a lower voltage for a longer time? These are questions which are still answered by opinions to a large extent. We do not as yet have all the facts definitely established which are essential to the formulation of the true answer.

What is the purpose of this particular voltage test? We encounter two serious obstacles when arriving at the suitability of a piece of cable. In the first place, the insulation is buried out of sight and in the second place, it is far from homogeneous. A member in a steel structure can be put in place with almost complete

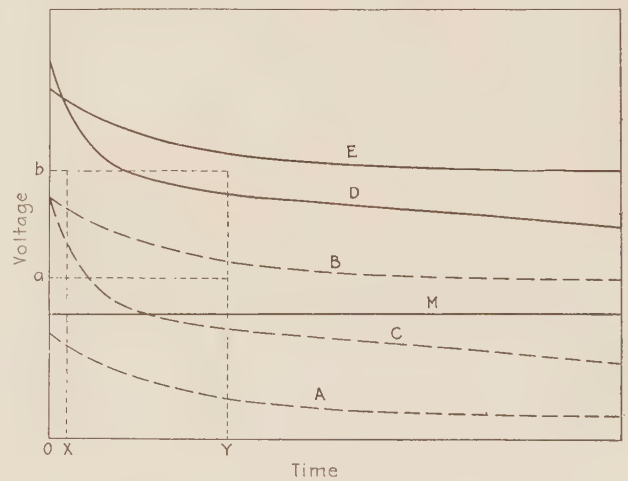


Fig. 3

confidence that it has 100 per cent reliability if it passes a visual inspection. But in the case of a length of cable we cannot judge by inspection whether it will serve the purpose intended nor can we depend absolutely upon a test to destruction of a specimen because of the lack of uniformity. We must "load" every foot of cable, that is, subject it to a voltage well above the

rated voltage—if we are to be assured of a reasonable "factor of safety."

The test should preferably accomplish two things,—eliminate cable the insulation of which is electrically weak because of accidental defects, and eliminate cable which is electrically weak because of the inherent low quality of insulation.

One way of visualizing the conditions with which we have to contend is indicated in Fig. 3. It is well established that the voltage which a given piece of insulation will withstand is greatly effected by the test conditions, one of the most important being the time of application of the voltage. Each portion of insulation has its own voltage-time characteristic which can be indicated in the general manner shown by the curves in the diagram.

Now, consider a section of cable with an accidental defect of a mechanical nature such as external damage to the insulation, registration of a large number of tapes, cracked or torn insulation, etc. The breakdown voltage of the section of cable will, of course, be that of the insulation at this point, and if the injury is serious, the breakdown voltage will be much below that of the rest of the section. Nevertheless, that spot has a time-voltage characteristic which we can indicate by curve A. But a moderate test voltage, a, even if applied only momentarily will cause puncture and therefore eliminate that section. If the defect is less extensive so that a lesser thickness of the insulation is effected, the curve may be something like B in which case, a test at a volts even if applied for y time, will not eliminate it. Nevertheless, its so-called permanent breakdown voltage, *i. e.*, the maximum voltage which it will withstand indefinitely is not sufficiently above the operating voltage, M, to provide the necessary factor of assurance. On the other hand, a test at b volts, even if only momentarily applied, would eliminate it.

Next, assume a spot which is inherently electrically weak due, for example, to incomplete saturation or overheating at a lead press mark. The insulation at that point may have a high momentary dielectric strength without a correspondingly high endurance strength due to high dielectric loss which causes failure in accordance with the thermal theory of Steinmetz and Wagner. The characteristic curve at this point might be of the shape indicated by curve C, in which case a test at a volts for a time x would not eliminate the section but a volts for y time would.

Normal cable may have a characteristic like curve E or curve D. The former is obviously the preferable type of curve. Both curves are higher than those for the other cases, consequently the test voltage should be adjusted to the normal cable and not to the abnormal cable only. The problem is then to determine the voltage which should be applied to insure as high a curve E as possible, and for as long a time as practicable in order to eliminate cable with too much of the characteristic indicated by D. This would be accomplished by applying b bolts for y time.

The practical question is then, what should the voltage be and for how long should it be applied? This question has been with us since the beginning of the industry and is likely to remain with us for some time to come. It is to be noted, however, that the trend in fixed voltage tests is very definitely upward both as to voltage and time. For instance, the A. I. E. E. rules adopted in 1911 prescribe double normal rated voltage for one minute. The standards of 1922 prescribe two and one-half times operating voltage for five minutes while those adopted August 6, 1925 prescribe three times the rated voltage plus 2 kv. for five minutes. The most recent specifications in wide use, namely, those of the Association of Edison Illuminating Companies, prescribe test voltages substantially in accord with the latest rules of the A. I. E. E. but the test period is fifteen minutes instead of five minutes. So, despite our lack of facts and figures, general knowledge and experience has gradually pushed up the test voltage and lengthened the time of application.

(*b*) *Short-time Breakdown Voltage Test.* The fixed voltage test will not of course tell us what factor of assurance we are getting. We try to get some light on that question by means of short-time breakdown voltage tests, *i. e.*, by testing short samples to destruction. The light we get, however, is rather feeble for after we have obtained the so-called momentary puncture voltage, we cannot coordinate it with the rated or operating voltage of the cable. This is due not only to the dielectric strength-time relation referred to in the preceding discussion, but to the variation in the material. The latter point could be taken care of by testing enough samples but any such procedure sufficiently extensive to truly represent the product would be quite impracticable. However, short-time tests do give us data which indicate the trend at least of the dielectric strength.

Table I shows a summary of a large number of tests made in 1923, 1924 and 1925 respectively on cable manufactured under the N. E. L. A. specifications. The results are reported in average volts per mil. Cables of all sizes and voltages are included, so that some common basis must be used.

TABLE I
DIELECTRIC STRENGTH OF CABLE

Year	No. of Tests	Average volts per mil at breakdown			Per Cent inc. in Average over 1923
		C-C	*C-S*	Average	
1923	260	291	283	287	. .
1924	290	307	284	306	6.6
1925	106	354	357	355	23.7

"*C-C*" — between conductors.
"*C-S*" — between conductors and sheath.

It is evident that the dielectric strength of cables has been steadily increasing—being nearly 25 per cent greater on the average in 1925 than it was in 1923.

(*c*) *Long-Time Breakdown Tests.* The preceding discussion has indicated that one of the most important things which we would like to know is the *maximum* voltage which each length of cable will withstand indefinitely. The only way to get this information is by a series of tests to destruction by subjecting several samples of the same cable to different voltages continuously until failure occurs. Sufficient tests of this kind will give data from which a reasonable reliable answer to the above question can be made. Such tests are, however, very expensive as much time is required and also a considerable amount of costly cable. However, the significance and importance of such information is being recognized and it is felt that we have reached a step in the development of the art where this knowledge is essential to further intelligent progress. The cost of acquiring the necessary data is secondary in view of the importance of cables in the electrical industry and the large amounts of money being invested in them.

A considerable amount of this kind of testing is being done—some by the manufacturers and some by the utility companies, particularly the Commonwealth Edison Company of Chicago. Electrical Testing Laboratories are also doing a considerable amount of this class of cable testing and some of the data shown in the accompanying diagrams are made available through the courtesy of its clients, particularly the High-Tension Cable Committee of the Association of Edison Illuminating Companies.

The results of about 30 tests of three-conductor cable of various sizes and voltages are shown in Fig. 6 where the maximum stress gradient at the conductor

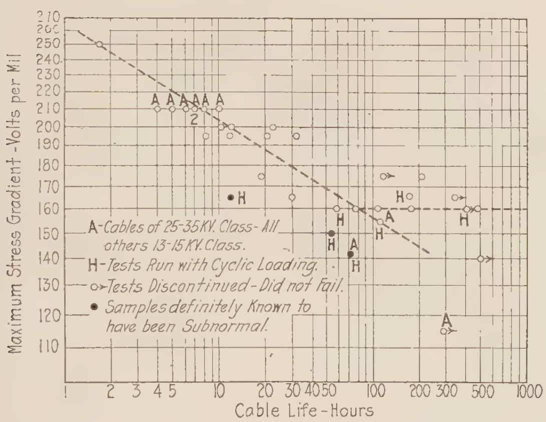


Fig. 6—Cable Tests (Time-Stress Diagram) Three-Phase Tests, Three-Conductor Cable

surface is plotted on logarithmic coordinates against time.

It will be noted that while the data are quite insufficient to justify anything like a final conclusion, they do suggest a more or less critical point in the life curve beyond which the cable will have indefinite life. That is, the broken line which is a reasonable mean of all of the points, suggests that, at a stress lower than about 150 or 160 volts per mil maximum stress gradient, the life will be indefinite (or at least will decrease at a very low rate) and that at higher stresses the life will vary inversely something like the seventh power of the maximum stress gradient. However, much more data are needed before this indication can be definitely established or disproved.

Fig. 7 shows some similar data, plotted in the same manner, which were obtained on 44 samples of single-conductor cable for very high voltages. If the points enclosed by the dotted line and which were obtained on specimens of two samples of cable that showed con-

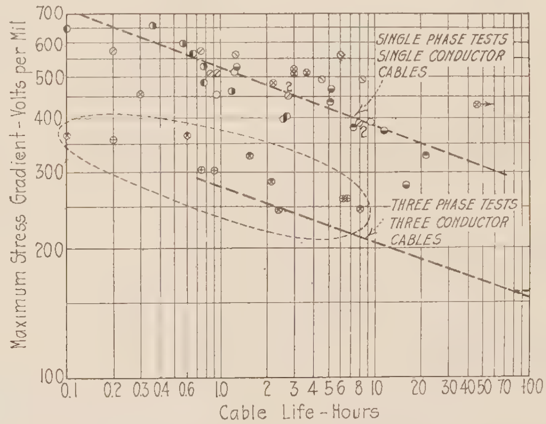


Fig. 7—Cable Life Tests (Time-Stress Diagram)

Note: Points show single-conductor tests only. For three-phase test points see Fig. 12. Designations identify makes of cable tested

sistently much lower dielectric strength than the other samples that are omitted, a fairly definite straight line can be drawn, as indicated by the broken line.

Whether or not a critical point exists here also is not determinable because we have not as yet enough data, specially long-time data. However, it will be observed that the slope of the curve as plotted is the same as that for the three-conductor cable in Fig. 6. The left-hand portion of the latter curve extended backwards is shown in Fig. 7. In other words, the seventh power relation between the maximum stress gradients is again suggested.

Dielectric Loss and Power-Factor Test

The practical significance of the dielectric losses in the insulation of cable was not fully appreciated until six or seven years ago when an epidemic of service failures led to the recognition of the dielectric loss type of failure. Bang and Louis[4] and other contributors to the Transactions of the Institute have discussed the influence of dielectric loss on the carrying capacity of cables. Roper[5] has given concrete evidences of cable failures due to excessive dielectric loss. However, these losses have been so much reduced that they are no longer a serious element in cable operation. In the

4. *Influence of Dielectric Losses in the Rating of High-Tension Underground Cables*, A. F. Bang and H. C. Louis, Trans. A. I. E. E., Vol. 36, 1917, p. 341.

5. *Dielectric Losses and Stresses in Relation to Cable Failures.* D. W. Roper, Trans. A. I. E. E., Vol. 41, 1922, p. 547.

past four years, the average loss in 30-kv. cable dropped from about 1.6 to 0.6 watt per foot and for 13-kv. cable from about 0.9 to 0.2 watt per foot.

Power-factor measurements also provide another means of studying the problem of uniformity of cable to which reference has been made.

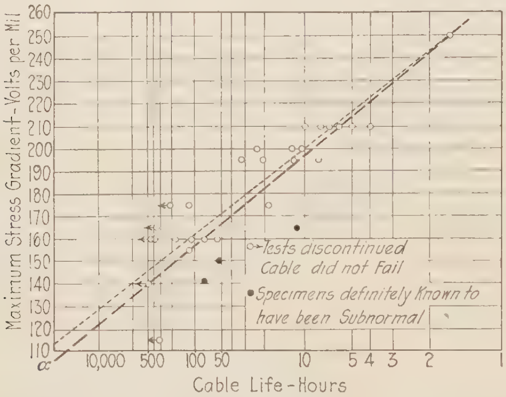


Fig. 9—Cable Life Tests (Time-Stress Diagram) Three-Phase Tests, Three-Conductor Cable

Fig. 11 shows some power-factor data for 13- to 15-kv., three-conductor cable made by various manufacturers during 1925, the upper line being values obtained at 80 deg. cent. and the lower line values at

TABLE II

City	Rated Kv. between phases	Thickness of insulation, inch	Stress Gradient volts per mil Average	Stress Gradient volts per mil Maximum	Remarks
Cleveland	66	30/32	41	79	In service
Philadelphia	75	30/32	46	82	Being installed
Philadelphia	75	26/32	53	89	On order
New York	132	23/32	106	160	Being manufactured
Chicago	132	23/32	106	160	Being manufactured

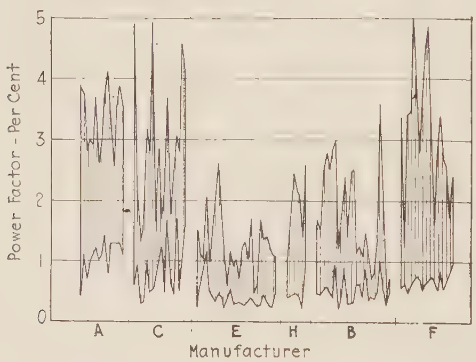


Fig. 11—Power Factor of 13-, 15-Kv. Cable, Inspected During 1925

Upper line—Power factor at rated voltage at 80 deg. cent.
Lower line—Power factor at rated voltage at 20 deg. cent.

20 deg. cent. It is evident the cable of manufacturer *A* was much more uniform in this respect at least than that of the others, particularly *C* and *F*. However, Make *E*, while not quite so uniform, was consistently much lower, with a minimum change between 80 deg. and 20 deg.

Several methods of making these measurements are in use and the suggestion has been made that one method should be adopted as a standard in order to eliminate some of the differences between different laboratories, but it is not believed that this is necessary or even desirable. What we need is not a standardization of one or more methods of making the measurement itself but a convenient *standard* load comparable in magnitude to the dielectric of a piece of cable.

Such a standard which gives promise of serving the purpose very well consists of three Leyden jars made of special glass, metal coated inside by silvering plus copper plating and outside with lead by the spraying process. The tubes are about two in. outside diameter, about 16 in. long and the glass is about $^3/_{32}$ in. thick. They are filled with oil and will withstand the application of 25 kv. continuously. With three-phase power factor at 25 deg. cent. of the particular set in the illustration is 0.22 per cent at 10 kv., 0.27 per cent at 25 kv. and 0.32 per cent at 50 kv. At 35 deg. cent., the corresponding power factor values are 0.24, 0.30 and 0.36 per cent.

"Ionization" Test

The work of many investigators in the field of insulation research has demonstrated that the less gas there is in the insulation the better it is as an insulator.

The so-called "ionization" test, a comparatively new one in the cable art, is intended to be a test of thoroughness of impregnation. We know that in a solid dielectric free from gas the loss will vary substantially as the square of the voltage and the power factor will be constant until the voltage approaches the rupturing value—barring, of course, temperature effects due to long application of the voltage. The theory of the "ionization" test is that, if air or gas is present, it will become ionized at a relatively low stress and the power factor will depart from a constant value as the voltage is increased, at a lower value than it would otherwise.

The "ionization" test, which is the present standard for specification purposes, is the determination of the change in power factor between an average stress of twenty volts per mil and one hundred volts per mil, respectively. The specifications issued by Association of Edison Illuminating Companies in November, 1924, prescribe that this change shall not exceed two per cent for a three-conductor cable or one per cent for a single-conductor cable.

The important question in connection with this test is, what is its real value? Will cable having a power-factor difference of two per cent for example, be better than one with a difference of four per cent and if so, in what respect and how much better will it be? Dr. Whitehead has shown[7] that insulating materials which were known to be poorly saturated had a high "ioni-

7. *Gaseous Ionization in Built-Up Insulation*, J. B. Whitehead, Trans. A. I. E. E., Vol. 42, 1923, p. 921, and Vol. 43, 1924, p. 116.

zation" test result and deteriorated rapidly under the application of voltage. However, we have no definite facts in the way of test data to show how much real gain is obtained in cables when this power-factor difference is two per cent instead of four per cent or one per cent instead of two per cent. Before reducing the permissible variation we should have definite knowledge on this point if such reduction involves increased manufacturing costs.

Bending Test

One of the most important tests in American cable practise is the bending test. It was introduced into cable specifications only five or six years ago but it has undoubtedly been an important factor in the marked improvement in workmanship and in the fabrication of the insulation of cables which has taken place. Excessive tearing was at first a common result in a bending test but now it is a rare occurrence. Furthermore, the insulation is tighter, more evenly applied and is practically free from wrinkles. Even in the case of cable with wood-pulp paper insulation, while there has been some improvement in the mechanical strength properties of wood-pulp paper, the improvements in fabrication processes have enabled such cable to pass this test—something that could not have been done two years ago.

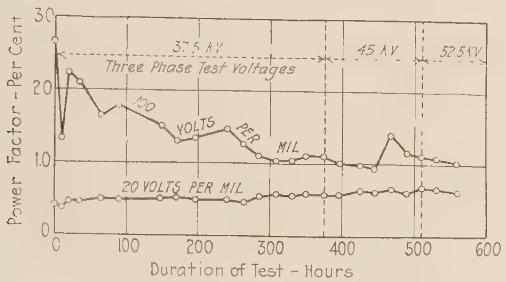


Fig. 16—Power Factor Variation with Time, Between Conductors

Combination No. 2. Rated voltage: 15,000
Insulation: paper, 14 x 10/32 in. *B C* and *B C L*
Conductors: 3-350,000-cir. mil sector

Table III shows in a striking manner the improvement that has been made in the ability of Manila paper-insulated cable to withstand this bending test, as measured by puncture tests. The figures given are grand averages of tests made on samples of cable of various sizes and voltages.

The last column shows what marked improvement has been made in the past three years—the effect of bending having dropped from 21 per cent to practically zero. In other words, present-day cable will withstand this severe bending test without any appreciable effect on the dielectric strength.

Tests of Components

Most cable specifications include some requirements, either general or specific, which necessitate certain tests to be made on most of the component parts of the cable. In addition, others not specifically required, are frequently made for the purpose of obtaining information.

Paper tests of paper removed from samples of cable are tested for composition of stock, tensile strength, tearing strength, folding endurance, dielectric strength and sometimes porosity or air resistance. Occasionally, also the dielectric constant is determined. Methods which are more or less standardized are usually employed for these tests but they will not be discussed here. It may be of interest, however, to note the general average value of some of the properties during the past three years, as shown in Table IV.

Tests of Compound. Few of the usual tests which are normally made on insulating materials can be applied to the compound in cables by the purchaser because the only way he can obtain sufficient quantities of a compound from the sample of cable is by extraction with benzol or other solvents.

A test that is frequently made is the determination of the approximate proportions of saponifiable and unsaponifiable constituents which are usually vegetable base and mineral base materials, respectively. It has been previously indicated that mineral base compounds have in general a much lower dielectric loss than vegetable base compounds but the latter has desirable viscosity and dielectric strength characteristics. A knowledge of the general composition of a compound is therefore useful as a check on the test results obtained on the cable itself.

TABLE IV
PROPERTIES OF CABLE PAPER (MANILA)

Year	Tensile Strength, lb. sq. in.*		Folding Endurance, No. double folds*		Tearing Strength, grams†		Dielectric Strength: Individual Tapes, Volts per mil		Dielectric Strength: Average Stress Gradient, Volts per mil‡	
	No. of Tests	Avg.	No. of Tests	Avg.	No. of Tests	Avg.	No. of Tests	Avg.	No. of Tests	Avg.
1923	150	7230	150	1010	150	180	..	..	260	287
1924	825	7350	825	724	825	179	56	589	290	306
1925(*A*)	273	8435	273	881	273	163	43	638	106	355
1925(*B*)	263	9250	263	620	263	170	78	649	40	369

*Parallel to strips.
†Across strips.
‡Repeated from Table III to show, as a matter of general interest the relation between the dielectric strength of single tapes and the dielectric strength of the total insulation (expressed in the same manner) as obtained in breakdown tests of samples of cable (before bending.)

A new test has recently been developed as the outcome of the unfortunate results which followed the change from vegetable base compounds to mineral base compounds in order to reduce dielectric losses which had

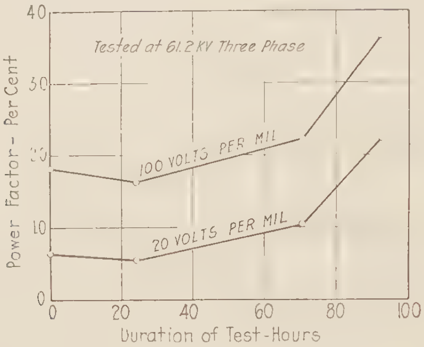
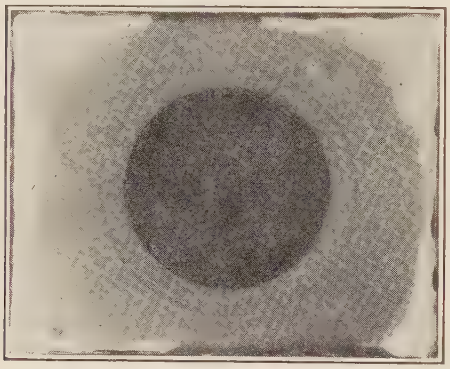
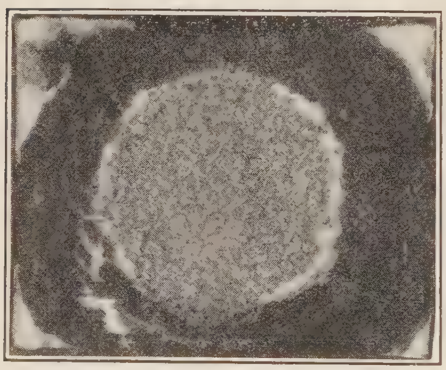


FIG. 19—POWER FACTOR VARIATION WITH TIME—BETWEEN CONDUCTORS

Combination No. 2. Rated voltage: 36,000
Insulation: paper, 33 x 25/64 in. *B C* and *B C L*
Conductors: 3-350,000 round



A



B

FIG. 26—WAX TEST

a. A specimen of petrolatum prepared for test
b. The same specimen after 48 hours at 600 volts per mil

been responsible for failures of the former type of cable. A few months service experience with the first high-voltage cables impregnated with mineral base compounds showed that an unknown, solid material, cellular in structure and extremely light, formed in the interstices of the insulation and failures too frequently followed in the course of time. It was evident, as is so often the case, that the elimination of one defect was being accompanied by the introduction of another.

In order to form this unknown material in any practical length of time, the compound must be subjected to stresses which are above the breakdown value. This is best done by placing the compound between concentric glass cylinders or between parallel glass plates. In the latter method as used at the Electrical Testing Laboratories, a film of the compound about three mils thick is placed between two lantern slide glasses on either side of which is a flat electrode to which the potential is applied. The upper electrode is removed at intervals and any change in the character of the film is noted.

Fig. 26 is a photograph of a test specimen before and after subjection to this test. Fig. 27 is a curve obtained with petrolatum which shows the time at which this unknown material, X, forms at various stresses—the stress being calculated from the measured dielectric constant of the glasses and the compound, the thickness

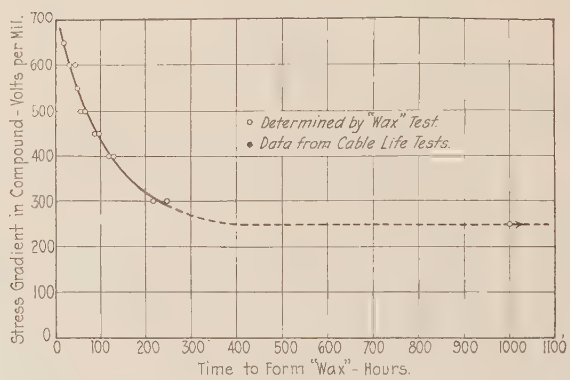


FIG. 27—WAX TESTS—TIME-STRESS DIAGRAM

of the glasses and the film, and the applied voltage. It seems reasonably safe to assume from the trend of the curve that in a sufficiently long time more or less X could be expected to form even at stresses existing in high tension cables in normal operation, that is, of the order of fifty to seventy-five volts per mil.

While the absence of any signs of disintegration in a compound when subjected to this test is not a guarantee that it will remain unchanged indefinitely in a cable,

TABLE V

Load lb.	Stress lb. per sq. in.	No. cycles of bending	Remarks
0	0	8710	First cracks noted
5	40	3400	First cracks noted
10	80	1900	First cracks noted
15	120	1000	First cracks noted
0	0	8100	First cracks noted
0	0	11000	Badly cracked
0	0	12000	Ready to break
10	80	2700	First cracks noted
10	80	3600	Badly cracked
10	80	4040	Broke

Note: First group of specimens from one piece of lead, other two from another piece.

it seems reasonable to assume that if 600 volts per mil for seventy-two hours at either room temperature or at 75 deg. cent. does not produce any change, the chances of disintegration taking place in service are rather remote.

Conclusions

The problem confronting the engineer responsible for an underground cable installation is the transmission of the most energy per dollar of annual cost, *i. e.*, per dollar of investment and per dollar expended in maintenance. The investment cost will depend not only upon the voltage employed, which presumably will have been selected after proper consideration of the economics of the situation and the local conditions, but also to some extent on the quality of the cable, for, the better the insulation, the less of it has to be used and the lower will be the cost. The maintenance cost, however, is largely a matter of quality although the cost of repairs due to inferior workmanship on splices, careless handling of cable during installation and other avoidable causes is not an insignificant item.

Every failure in a cable costs money in direct outlay for replacement of cable and for withdrawing the old cable and installing the new, in addition to splicing and other incidental expenses. There is the further effect of cable failures that cannot be evaluated, namely, the disturbance to the service, the continuity and dependability of which is such an important element in the "good-will" of an electric public utility.

The record of cable failures quoted above might be considered good and perhaps it is in comparison with the records of other electrical apparatus, particularly when the comparison is on the basis of the area of insulation involved. But it is the function of the engineer to make the record better and thereby reduce the maintenance cost in which cable failures form so large a part.

It is obvious that the greatest reduction in the number of cable failures is to be effected through improvement of the quality and through improvements in the design. Progress in both of these directions can be made in the following ways, all of which involve comprehensive and systematic testing of the kinds discussed in this paper:

(1) *Research by both manufacturers and users.* It is the manufacturers' problem to improve the quality of the materials which make up a cable. It is also their problem to improve manufacturing processes in order to produce cable which is not only better cable but which is more uniform. It is the users' problem to carry on investigations which will provide information that will permit more efficient operation based on facts rather than opinions and which will indicate the direction in which improvements are needed to meet the present and future requirements of the industry.

(2) *Thorough and systematic inspection and tests of cable when purchased.* While the immediate, primary purpose is to insure compliance with the contract, the greatest value of inspection and tests is likely to be the fact that it provides the means of obtaining definite, quantitative knowledge of the quality of cable. Such knowledge must be available before a reference point can be established and progress accurately measured.

(3) *Evaluation of cable.* The development of a satisfactory method of quantitatively evaluating cable through suitable weighing and combining the results of inspections and tests would provide a very useful incentive to progress.

(4) *Specifications.* Cable specifications must, of course, be based on current practise and consequently revisions of existing requirements must follow progress in the art. However, keeping specifications up to date so that they include advances as they are made does, in itself, contribute to the general progress through setting a high standard for *all* manufacturers and for *all* users rather than the *few*.

(5) *Periodic examination of cable in service.* Improvement in cables would unquestionably be greatly aided if we had more knowledge of what takes place in a cable which causes it to deteriorate and ultimately fail. Apparently all of the equipment on the system is given a more or less systematic inspection except the cable which is buried in the ground and forgotten until trouble develops. Samples should be removed when a convenient opportunity is afforded and examined and studied so that we can learn, if possible, what it is that determines the life of the cable and thus aid progress by indicating the direction of improvement both in the cable and in the specifications for the cable.

NEW TRAFFIC SIGNALS FOR CHICAGO

On February 7th, new traffic signal equipment went into service in the *Loop* district in Chicago at forty-nine street intersections. All this apparatus, equipped with three-light traffic signals at each corner, is served from underground circuits terminating at the City Hall where a central control board is located. This board provides an extremely flexible control, it being possible to vary the intervals between traffic halts at intersections along the same street. The ratio between periods on intersecting streets may likewise be varied. The control board was built under the specifications of the Department of Gas and Electricity.

New traffic-control equipment is also being installed outside the *Loop* district on eighty-seven intersections, some involving three streets. These signals are controlled by local panels which also permit flexible combinations of operation. Energy for the units outside the loop will be furnished by the Commonwealth Edison Company. Signals within the loop will be operated between 7:30 a. m. and 12:30 midnight.

Some Interconnected-System Operating Problems

BY FRANK G. BOYCE[1]

Member, A. I. E. E.

Synopsis—*This paper outlines the advantages and disadvantages of an interconnected system consisting of steam and hydroelectric stations. Investment costs are materially reduced because of less reserve capacity being required to insure continuous service. More efficient operation of generating units is possible and operating costs are reduced. Electrical disturbances are magnified and large generating stations must be located near the heaviest load centers so that the system may be split up to localize disturbances. A well-trained corps of load despatchers must be available and they must be fully informed of all conditions on the system which may affect operation.*

* * * * *

MUCH has been said and written of late regarding interconnected systems. In fact, "superpower" and "giant power" are almost as popular today as radio. Magazines and the daily news contain much information and misinformation on the subject.

The purpose of this paper is to bring out some of the economic and operating problems which must be kept in mind in the design and operation of an interconnected system of steam and hydroelectric generating plants and to show how these problems have been solved in some instances.

It must be kept in mind that while people in the metropolitan centers are accustomed to a very high quality of service, yet in the smaller towns and suburban sections the use of household appliances, electric refrigeration, electric cooking, water pumping and miscellaneous small motor uses are now quite common and are increasing at an amazing rate. These uses are demanding that the small towns and villages receive the same grade of service that the large cities have enjoyed and at the same time the investment must be kept sufficiently low so that this service can be furnished at a rate which will encourage the use of electrical energy and will compete with isolated plants.

The investment in generating equipment per kw. of installed capacity can usually be kept lower by interconnection, for it is possible to adequately safeguard service with a lower investment in reserve equipment, as reserve in any section of the network is available to supply demands in other sections and practise seems to indicate that sufficient reserve to replace the loss of the largest single generating unit is adequate.

Usually maintenance work can be so scheduled that it can be carried on in the hydroelectric plants during the period of minimum stream flow; likewise, work of this nature can be carried on in steam-generating plants during the period of maximum flow. This work can also be so arranged that only a predetermined amount of capacity on the entire system will be out of service at one time. By following the schedules given above, the greatest amount of the combined capacity of the entire system is kept available at all times which assists in keeping the amount of reserve capacity to a minimum.

1. Consumers Power Company, Jackson, Mich.

To be presented at the Regional Meeting of District No. 5 of the A. I. E. E., Madison, Wis., May 6-7, 1926.

Interconnection has made possible the greater use of automatic generating equipment, especially in the smaller hydroelectric plants. Very often the cost of maintaining operators at small hydro plants makes the cost per kw-hr. delivered from these plants so great that these plants become a liability. As systems grow in capacity, the smaller plant becomes less important with reference to the system demand, its principal value being the kw-hr. it can deliver to the system. In such a case, if the plants can be made sufficiently automatic to operate so as to obtain the most efficient use of the available water, their operation can be made profitable and others developed, provided the investment can be kept sufficiently low. It is thought that there is room for development along the lines of cheaper and simpler methods for accomplishing this. In some cases the small plant may be made semi-automatic, requiring only a simple means of opening the oil circuit breaker and shutting down the waterwheel. A number of such installations, some of them rather crude, have been in successful service for years.

Consideration should be given to the location of generating units at strategic points in the network with reference to the load centers. In some cases, generating units can be so located that a transfer of any large amount of power over a great distance will be unnecessary. In considering the location of generating units, some thought should be given to the sectionalizing of the system at times of serious trouble in one portion of the network. If this is done, the trouble will be confined to the smallest possible area. It is sometimes desirable to sectionalize the system when severe lightning storms occur over a portion of the network so that surges caused by lightning strokes will not be transmitted to other parts of the system.

The combination of steam and hydroelectric plants in one system allows the most effective use of the kw-hr. capacity of the hydroelectric plants and at the same time allows the operation of steam generating plants at their most efficient loads.

A greater number of hydroelectric units can be operated during heavy load periods, permitting the elevation of the storage reservoirs to be lowered slightly. During low-load periods a greater percentage of the system load can be carried by the steam generating units, allowing the hydroelectric reservoirs to return

to their normal elevation so that the hydroelectric generating plants are ready to repeat this cycle of operation at the return of the heavy load.

When a large number of plants are feeding into one network, all hydroelectric units can be operated at the most efficient gate openings at all times, thus obtaining the maximum kw-hr. output from the available water; likewise steam generating units can be operated at their most efficient loads. Changes in the system load can be taken care of by starting up or shutting down units.

Tests can be made which will determine the most efficient load at which boiler units will operate and as the system load requires, additional boilers can be fired or banked, or additional steam turbine units can be brought into service.

The efficiencies of steam generating plants are greatly increased by operation in conjunction with hydroelectric plants, because although the hydrostorage reservoirs may be small, yet the great flexibility of hydroelectric plants, due to storage reservoir capacities, permits the changing of loads on steam generating plants in blocks according to the most efficient load which can be carried on boiler and turbine units then in operation. The extent to which this can be carried out will be realized when it is pointed out that on a system having 10 steam generating plants ranging in capacity from 400 kw. to 40,000 kw. (some of these plants being rather old ones) a system of fuel economy for one year of approximately 21,000 B. t. u. was obtained, while if these plants were operated as isolated ones, the B. t. u. per kw-hr. would have been considerably higher.

It is also possible to obtain a greater kw-hr. output from hydroelectric plants operating as a part of one of these systems. As an example, one hydroelectric plant which has been operating for a number of years as part of an isolated system at a yearly output of 2,006,600 kw-hr. was recently made a part of a combined system and the output was increased to 2,797,900 kw-hr. per year.

It has been found that the efficiency of both hydroelectric generating plants and steam generating plants can be improved by dampening the governing mechanisms so that all of the plants will operate as base-load plants except with such capacity as is necessary to maintain system regulation. The governors on the hydroelectric units will be so set that they will be operating at the most efficient gate opening and at the same time governors on the steam generating units will be so arranged that they will be operating at their most efficient loads. This is made more certain on the steam generating units by the installation of what might be called a "load limiting device," which is attached to a General Electric turbine, as shown in Fig. 1. This device prevents the governor valve from opening beyond a certain amount, preventing the unit from carrying more than a predetermined amount of the system load. This does not in any way endanger the operation of the unit, for if the unit would be suddenly relieved of its load or should speed up for any other reason, the governor will function normally. This device can be so set that any predetermined amount of load will be carried by the unit, which amount can be changed very quickly by the operator. The hydroelectric units can be equipped with "load limiting devices" very similar to the above in order that these units can be set to operate at their most efficient gate openings.

The mechanical and electrical design of these plants can be much more simple than isolated plants. The electric equipment will usually consist of one bank of step-up transformers with its high-tension and low-tension circuit breakers. It will also contain one set of low-tension busbars with an oil circuit breaker for each generator and one bank of transformers to supply power for station auxiliaries.

In some cases it is feasible to omit the low-tension busbars and oil circuit breakers, installing a transformer bank for each generator with oil circuit breakers on the high-tension side of the transformers. These plants

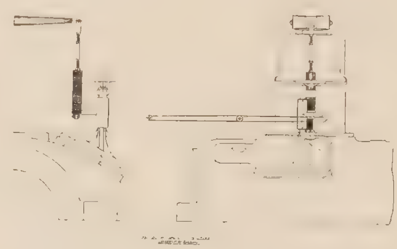


Fig. 1—Assembling of Load-Limiting Device Installed on 20,000-Kw. Turbine

require very modest expenditures for buildings as in most cases the transformers and in some cases the busbars and oil circuit breakers are installed outdoors.

The mechanical design is simplified by the elimination of many of the otherwise necessary duplicate station auxiliaries. The auxiliaries can in most cases be electric driven, obtaining their supply of power from the main busbars. If in an extreme case these auxiliaries should fail, a momentary interruption to the plant would probably result but would perhaps be unimportant, as the system load would be carried by reserve in the other plants until the plant which is in trouble is returned to service.

One item of very great importance in the mechanical design of hydroelectric plants is the facilities for spilling water, should the plant be suddenly relieved of its entire load. This is especially important in low-head plants where the storage capacity of the reservoirs is limited. Plants designed for interconnection are often connected to transmission systems by one bank of transformers or a single transmission line and do not supply a local power load, in which case an interruption to either of these removes all load from the plant. Arrangements must be made immediately to take care of stream flow.

One of the early methods used consists of a Tainter gate arranged to be raised by an electrically driven winch, operated by means of a crank in case of total interruption to power supply. This device was fairly satisfactory although in this climate it was found necessary to keep the gate free of ice, an operation requiring considerable manual labor. This type of gate was later improved upon by totally enclosing and installing steam coils inside the housing; thus, the gate could be held at a temperature that would keep it free from ice. This requires considerable fuel to maintain proper temperature.

There are a number of other methods in use, including the different types of conduit spillways in which the amount of water spilled is controlled by means of gate valves, butterfly valves or Broome gates. These methods are successful and have some advantages over the Tainter gates, aside from overcoming the ice problem.

As the length of transmission lines involved in a network and the connected capacity increases, the frequency and severity of disturbances is apt to increase. This should be kept in mind particularly when large metropolitan centers are concerned with large blocks of power concentrated in small areas. Insulation which is adequate for a system consisting of short low capacity lines will be entirely inadequate as the system grows. Thus, it is often found necessary to completely rebuild transmission lines and substations and install oil circuit breakers of greater rupturing capacity, replacing apparatus which was adequate in itself, before these units can be made a part of a larger transmission system.

A study of the proposed location of transmission lines with reference to the paths generally taken by storms is desirable in order that such lines can be so located that they will least be affected by these disturbances. Where more than one line is to be built between two points, it is often desirable to locate these lines on entirely separate rights-of-way so that all transmission lines will not be subjected to atmospheric disturbances at the same time.

In designing transmission lines, it must be remembered that materials used in their construction, such as steel, cement, porcelain, copper and aluminum, are exposed to the air, subject to all of the ravages of the elements—extremes of heat and cold, vibrations and strains caused by wind and heavy loading by sleet. It has been found that, especially in the northern climates, action of the weather has a deteriorating effect on the ordinary mixtures of clay and cement. The subjecting of these materials, with their different coefficients of expansion to the varying conditions of moisture and temperature, has caused unthought of failures requiring research and continuing improvement in design.

Periodic inspections of transmission lines by patrolling are advisable for a number of reasons, particularly in the more thickly settled districts. It has been found that patrols made on foot are most satisfactory. The frequency of patrolling depends largely upon the design and location of the particular line and also upon its importance.

With frequent regular inspections, the possibility of wire failures is considerably reduced, patrolmen often detecting burned spots on the wire caused by flashovers which later, particularly in the strain of the cold weather, will undoubtedly result in transmission line failures.

The elimination of tree conditions is another factor which should be given careful attention, proper pruning of trees is necessary and in some cases their removal is desirable. A close watch should also be kept for the possibility of people either erecting or moving buildings under the lines, as persons engaged in this work often do not realize the danger from high-tension wires. All such matters can be watched closely by the man who is constantly covering the line. The patrolman becomes more or less acquainted with all of the people living along the line and is able to impress upon them the possibility of danger from carrying on such work. This generally results in the patrolman being advised when matters of this kind are contemplated; thus arrangements can be made for a prearranged interruption of the line, if necessary, while the work is in progress.

In addition to the regular patrols of transmission lines, it is thought quite desirable to institute special patrols after a transmission line has been exposed to severe storms or when transmission lines have shown indications of trouble and have been returned to service without the fault being discovered.

On some systems it has been found desirable to carry on practically continuous testing of transmission-line insulators and in so far as the older insulators are concerned, this is still in most cases necessary.

Improvements which have been made by the manufacturer from lessons learned by experience in the field has produced an insulator which has an extremely low rate of deterioration for at least a period of from 10 to 12 years. While it is, of course, necessary to watch the insulators during this time, it is not thought so vital that they be continually tested.

Various kinds of tests have been in use but it now appears that the 60-cycle, high-voltage test is the most satisfactory.

In order to constantly improve the operation of generating plants and to increase the output of hydroelectric plants, an adequate system of station records must be maintained. Each station should be supplied with log books in which is recorded all operations which are carried out, also information relative to conditions leading up to each operation. Where operations are performed under instructions from foremen or supervisors, a notation should be made indicating from whom these instructions are received. These log books are

very useful in making studies of past operations and in showing how improvements can be made.

Rain gages should be maintained at each station in order that records of precipitation may be kept. These records are sometimes taken in cooperation with state authorities, in which case they become official government records. These records should be compared with run-off so that probable hydroelectric outputs can be estimated in advance. After heavy rains or in advance of spring floods, reservoirs can be so drawn down that the maximum amount of excess river flow will be utilized.

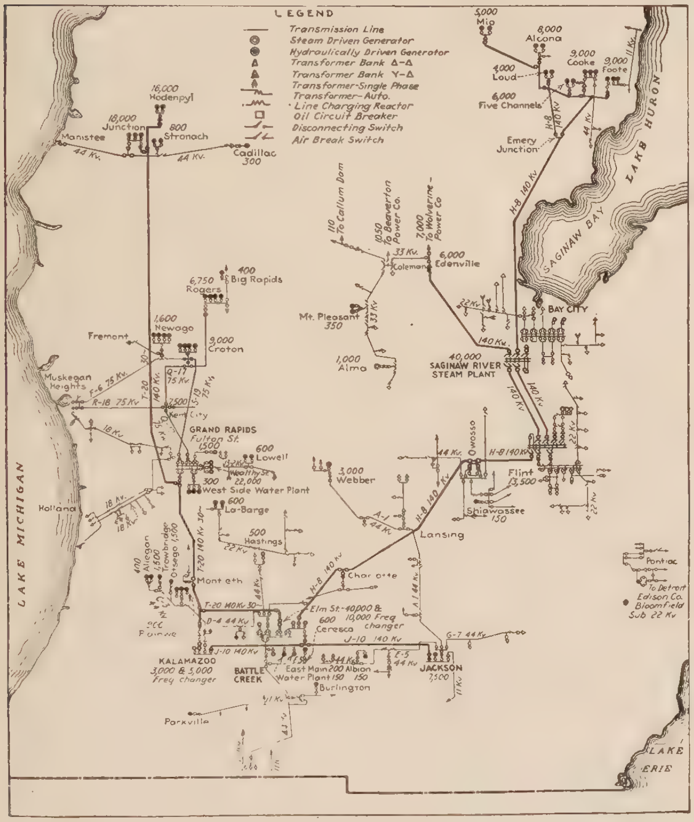


FIG. 2—MAP OF CONSUMERS POWER COMPANY SYSTEM

It is necessary that operators of these systems be constantly on the alert to detect any weaknesses which may be developing—thus faults may be detected before they have interfered with service. In order to accomplish this an adequate system of inspection and tests must be maintained.

Adequate means of communication between stations and the load despatching department is quite necessary for economical operation and in emergencies will assist, by locating faults and transmitting switching orders, in restoring service with the least delay.

An identification scheme for lines and switches will greatly facilitate transmission of orders and avoid mistakes. This scheme should consist of symbols which are not easily confused in discussion over telephone lines. This will avoid the possibility of incorrect operation of switches.

One of the very essential factors necessary for successful and economical operation is an adequate load despatching system. Such a department should be furnished with information showing efficiencies of both hydroelectric and steam generating units at different loads, delay of water between plants in series on the same river, rate of run-off from precipitation, relative storage above hydroelectric plants so that sufficient water can be passed from one plant to another on the same river and thus keep them all operating at the highest efficiency. The men must be kept acquainted with the loads to be carried and with any unusual conditions which will affect hour-to-hour operation. It is desirable to have these men acquainted with the condition of equipment in all the plants with reference to its ability to carry load; no apparatus affecting the capacity of any of the plants should be taken out of service without the advice of this department. Station operators should supply the load despatchers with frequent operating reports so that loads can be adjusted between plants and at the same time make sure that sufficient excess capacity is in service to take care of emergencies.

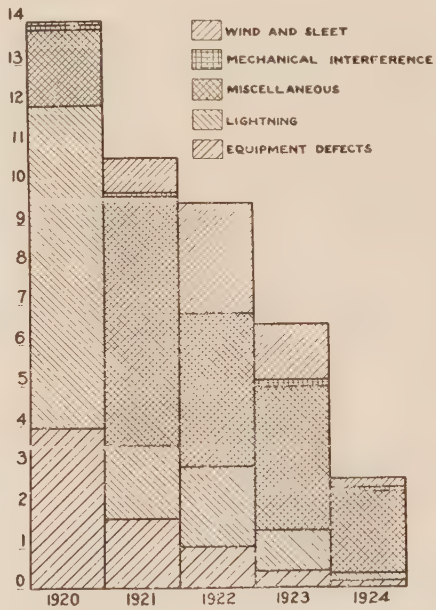


FIG. 3—CHART SHOWING COMPARATIVE REDUCTION OF TRANSMISSION-LINE INTERRUPTIONS

Some means is necessary to give the load despatcher a visual record of the position of switches. A method which has been used instead of the more elaborate electrically operated device is a small board consisting of a single-line diagram of the system laid out geographically, mounted on a thin wooden panel, backed by a bank of red lamps. Small holes of about 3/16-in. diameter are drilled through each switch location. Rubber plugs that can be readily pushed through and out of the holes with the point of a pencil are inserted in the holes to represent closed switches. The open

holes allow the red light to show through, representing open switches.

Each station should be provided with written instructions covering emergency operation of switches and lines—thus in case telephone communication is interrupted, operation can continue and interrupted service be restored.

The author has based many of his conclusions on the results of his experience with the system of the Consumers Power Company of Michigan, which has had to confront many of the problems to be considered. Fig. 2 is a map of this system showing 600 miles of 140-kv. transmission lines suspended in the form of a "U." There are 1100 miles of transmission lines from 22-kv. to 75-kv. in addition to the 140-kv. backbone connecting 44-steam and hydroelectric generating plants with distribution centers consisting of several moderate sized cities and a larger number of towns and villages. The west side is made up of 30-cycle equipment and the east side, 60-cycle, connected together at two points with 5000-kw. and 10,000-kw. frequency changers.

The extent to which these facilities can be made workable and the results which can be obtained are indicated to some extent by Fig. 3, showing the relative improvement of transmission-line operations with reference to interruptions to substation supply, involving lines of 22 kv. and above, including the transmission line itself and associated high-voltage apparatus in stations and substations. All interruptions are evaluated on a kv-a-mile-a-minute basis.

The causes are divided into five groups; Lightning, Wind and Sleet, Mechanical Interference, Equipment Defects and Miscellaneous. The mechanical interference group represents trouble due to foreign objects blowing into lines, automobiles and trucks leaving the road and striking poles and towers, and other similar troubles.

The miscellaneous group includes testing and inspection, interruptions necessary to take care of construction and maintenance work, unknown causes and mistakes. Prearranged interruptions to take care of construction and maintenance work represent about 90 per cent of this group. The continuing reduction in the interruptions from all causes shown by these graphs brings out clearly the improvement that is being made in both operation and design.

STREET LIGHTING BEGAN IN 1414

Street lighting began in 1414 when a city ordinance in London required every house and store owner on certain streets to hang out at least one horn-sided lantern at sunset. Paris, in 1558, led the world in municipal street lighting when it installed tall vases at important street corners in which pitch was burned each night with flickering, sooty results. These various crude outdoor lighting methods strove ineffectually for more than 450 years to achieve what the electric carbon and filament lamps have done in the last 40 years.

Discussion on Alternating-Current Analysis

ALTERNATING-CURRENT ANALYSIS[1]

(R. D. Mershon)

V. Bush (Communicated by letter): The total power in any network must evidently be supplied by the source. Similarly the algebraic sum of the separate reactive kv-a. in the separate branches must also be supplied from the source as excitation to the system. This applies to a system in which all voltages and currents are of the same frequency, irrespective of how the system may be interconnected. It is a very useful principle, and I have been using it with classes at the Massachusetts Institute of Technology in the form given by Dr. Mershon, since he first called it to my attention sometime ago.

Another way of looking at the matter is this. Again dealing only with a single frequency: the excitation or quadrature kv-a. which must be supplied is given by the amount of iron or air carrying flux, the permeability of the iron, and the flux density; and on the other hand, the amount of stressed air or dielectric, the dielectric constant, and the electric flux density. Specifically the net excitation, to be derived from rotating machinery, is given by the difference between the stored magnetic and electric energies, or

$$\int \left(\frac{B^2\, d\, v}{8\, \pi\, \mu} - \frac{E^2\, d\, v}{8\, \pi\, K} \right)$$

a volume integral. This is entirely independent of how the system is connected, the number of phases, and so on. In other words, if a certain weight of iron of known permeability is to be excited to a definite flux density, the excitation kv-a. requirement is the same no matter where the iron is placed or how related to the circuit. Also the contribution of the dielectric toward this excitation depends only on how much there is of it, its dielectric constant, and how high it is stressed.

It is a somewhat different matter when we consider the iron to be of varying permeability. There are then always harmonics introduced either in voltage or current, but not necessarily in both. It would seem that the amount of these harmonics should, in some fundamental way, depend upon the amount of iron present, its hysteresis loop and its maximum flux density, independent of the circuit connections. However, such a general principle is not available, largely because there is no ready way of specifying what is meant by the amount of harmonics present in the network. If such a conception could be arrived at in useful manner it would enable us to treat the harmonics produced by transformer banks with somewhat the same facility that the present principle affords for the computation of the apparent power of the network.

H. H. Race (Communicated by letter): In the recent paper on "Alternating Current Analysis" presented by Mr. Mershon he claims that the material he covered had not previously appeared in print. This has been taught for years as an elementary method for the solution of such problems and may be found in several much-used Electrical Engineering text-books.

My first reaction to Mr. Mershon's paper was to wonder why he should present the old long-hand method for the solution of such circuits, why he should prefer to use long expressions involving squares and roots in preference to representing vectors and operators by complex numbers.

Then I asked myself the opposite question, what advantages would result from the solution of such circuits using complex numbers. There are at least three:

(a) *The use of complex numbers allows the solution to be carried through in short symbolic equations.* The advantage of this would be much more apparent if Mr. Mershon had chosen circuits having more combinations of series and parallel circuits than he has shown. His equations are very unwieldy and would become much more so if the circuit were made more complicated.

1. A. I. E. E. Journal, January 1925, p. 43.

In symbolic form the total current in Fig. 3 may be obtained as follows:

$$i = \frac{e}{Z_{total}} = \frac{e}{Z_{12} + Z_{23}} = \frac{e}{\dfrac{1}{Y_1 + Y_2} + \dfrac{1}{Y_3 + Y_4}}$$

where Z and Y represent respectively the complex expressions for the impedance and the admittance of the branches denoted by their subscripts.

Compare this with equation (**19**) and we see that his C is the equivalent impedance of the whole circuit, although he does not call it such. If one were to solve the symbolic equation above, the actual computations necessary would be the same as those required for the solution of equation (**19**) but how much easier it is to obtain an expression for the current by the symbolic method.

(*b*) *A solution expressed in simple symbolic equations makes much more apparent the steps involved when one person is trying to understand the work of another.* This is important, else what is the use of engineering literature.

(*c*) *The use of complex numbers by engineers should be encouraged rather than discouraged* because so many problems are easily solved by their use, which are exceedingly laborious, if possible at all, using the long-hand method. For example, consider circuits having distributed constants.

Discussion at Midwinter Convention

TRANSMISSION SYSTEMS WITH OVER-COMPOUNDED VOLTAGES[1]

(DWIGHT)

NEW YORK, N. Y., FEBURARY 8, 1926

L. F. Woodruff: One of the chief problems encountered in the calculating of the most advantageous amount and phase of compounding for the generator-end voltage of a transmission line is the determination of the settings required to locate the receiver power circle center at a predetermined point. This problem is more involved than that of finding the center of the circle for given regulator settings, and while it is possible of

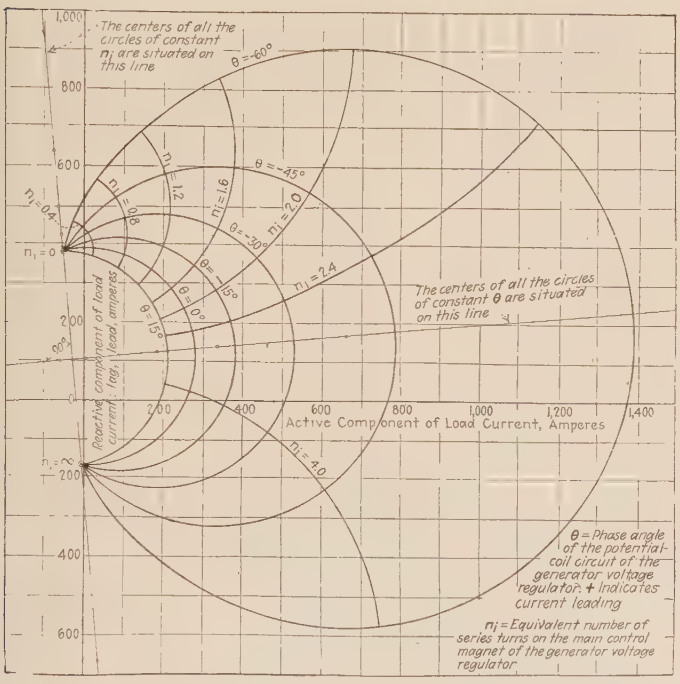


FIG. 1—CHART SHOWING AMOUNT AND PHASE OF COMPOUNDING AT GENERATOR END REQUIRED TO LOCATE THE CENTER OF THE LOAD CURRENT OR POWER CIRCLE AT ANY DESIRED POINT. LOAD VOLTAGE IS CONSTANT

explicit solution, such a solution is so cumbersome and involved that it is practically useless. Yet the logical approach to the problem is to try different circles of load power until the one is found which affords most economical operation, considering line and transformer losses, synchronous reactor losses and costs, voltage rise on the line, and stability. Then, having located the circle from economic considerations, the problem becomes that of finding the regulator settings required to make this the operating circle of the system.

Mapping of Power Coordinate Plane to Show Effect of Various Degrees of Compounding. I have found that the best method of solving this last problem is to draw on the load-power coordinate scale curves which map out the region in which the center is to be located in terms of parameters which indicate the amount of compounding. Certain features of these curves render their calculation and construction very much simpler than is at first apparent.

Fig. 1 herewith shows the amount of compounding required to locate the center of the load-power circle at any desired point, for a transmission circuit consisting of a 250-mi. line with terminal transformers. This figure has already been published[2], and the details of line, transformer and regulator constants may be found in the original references. In connection with it now I wish to point out these facts:

1. The center of the load-power circle, with constant load voltage and with generator voltage compounded, may be located anywhere on the chart.

2. For a given amount of compounding, the location of the center depends largely on the phase of the compounding.

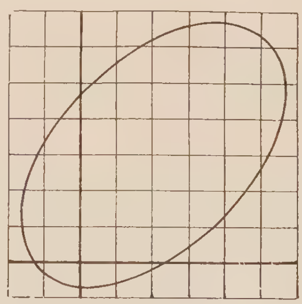


FIG. 2—ORIGINAL ELLIPSE DIAGRAM OF POWER AT LOAD END OF LINE WITH VOLTAGE COMPONDED AT BOTH ENDS

3. The curves of constant amounts of compounding, but various phase angles, comprise a family of circles whose centers, for a constant load voltage, all lie on a straight line passing through the center of the circle diagram for ordinary constant-voltage operation, and another point in the third quadrant corresponding to theoretically infinite compounding. The curves of constant phase angle, but varying amounts of compounding, comprise another family of circles passing through the two points just mentioned. The phase of the compounding can be adjusted by putting a reactance and resistance in series with the potential coil of a voltage regulator, instead of only a resistance, and while this has not been done in practise, it offers opportunity of improvements in line control.

1. A. I. E. E. JOURNAL, January, 1926, p. 25.

2. L. F. Woodruff, Regulator Settings for Long Lines, *Elec. Wld.* 1924. Also Principles of Electric Power Transmission (Wiley), 1925.

Voltages at Both Ends Compounded—Load Power Ellipse Transformed to Circle. Since graphical methods are so advantageous in shortening or eliminating calculation, and since the main advantage of circle diagrams over others which could present the same information lies in their easy preparation, a method of transforming the "ellipse diagram" which Professor Dwight derived, into a circle diagram, should be of some interest and value.

Fig. 2 represents an ellipse diagram plotted on rectangular axes. To transform this to a circle diagram, let one of the scales be such as to make the major axis of the ellipse lie along the 45 deg. line, unless it already conforms to this condition.

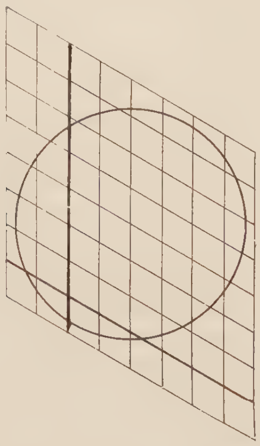


FIG. 3—ELLIPSE DIAGRAM OF LOAD POWER TRANSFORMED TO A CIRCLE DIAGRAM BY SKEWING THE AXES

If the original angle of this axis with the horizontal is θ degrees, the change to 45 deg. may be accomplished by using a vertical scale equal to the horizontal scale multiplied by tan θ. Now suppose the major and minor axes of the new ellipse to be of lengths A and B respectively. By skewing the axes as shown in Fig. 3, so that the angle between them in the first quadrant is 2 $\tan^{-1}\left(\frac{A}{B}\right)$, the ellipse is transformed into a perfect circle, and so may be drawn at once with a compass.

CURRENT LIMITING REACTORS WITH FIRE-PROOF INSULATION ON THE CONDUCTOR[1]

(KIERSTEAD)

NEW YORK, N. Y., FEBRUARY 9, 1926

V. M. Montsinger: The general tendency today is to make all electrical apparatus as fool-proof as possible. This is especially true of apparatus applied to protect other apparatus. In other words when the safety of other apparatus worth many thousands of dollars is dependent upon the proper functioning of a reactor it becomes doubly important to make the reactor as nearly perfect as possible. Mr. Kierstead's paper shows a marked advance in the art of making a dependable current-limiting reactor.

I well remember some of the early designs a few years ago, which were built by spacing bare copper cables by means of wooden supports notched to hold the conductors in place. Obviously a reactor having its turns supported by a combustible material, like wood, would not stand a very high temperature on short circuit, certainly not over 150 to 175 deg. cent. It was soon realized that a reactor of this design would not meet the severe conditions demanded of it. When the cast-in concrete type was developed and perfected it was thought that the problem of building a perfect reactor was solved.

But it was not long before someone left a bolt or a nut near a reactor and when a short circuit came on, the loose metal was drawn into the reactor by the magnetic forces set up, and the reactor failed to perform its function. A new problem had appeared which must be solved. This problem was not an easy one to solve because it was a difficult matter to obtain an insulation with sufficient toughness to resist the cutting or bruising action of a bolt hurled against it and at the same time to withstand a temperature of 300 to 400 deg. cent. without becoming charred. Some of the early forms of asbestos insulation were not satisfactory because they contained an appreciable amount of cotton, which soon burned out and weakened the fabric. Mr. Kierstead's efforts have succeeded in obtaining practically a 100 per cent asbestos insulation which is entirely satisfactory and we now have once again a reactor which appears to be practically perfect.

It is to be hoped that operating engineers who are dependent upon these reactors to protect large and expensive apparatus will appreciate Mr. Kierstead's efforts in producing a product so nearly proof against failures.

S. I. Oesterreicher: While I am in hearty agreement with many of Mr. Kierstead's statements regarding the insulation of current-limiting reactor conductors, still I regret very much not being able to give him full credit for his interesting conclusions.

As far as covering of reactor conductors is concerned, originality belongs to Mr. Philip Torchio and Mr. H. R. Woodrow, As far back as 1912, these two gentlemen designed and put in service current-limiting reactors in which the conductors were insulated partly with asbestos and partly with a rubberized tape.

Due to the increased generator rating and voltage of the circuit on which some of these first reactors were installed, they became obsolete and we had occasion to dismantle and inspect them.

On some of them the insulation after about 12 years of service was not impaired in the least and would have been good for many more years of service.

There is no question in my mind about the necessity of covering the reactor conductor with an insulation if reliability is sought. I believe that under normal operating conditions, if foreign materials are dropped or drawn into a bare conductor of a reactor, the effect will be far more serious than Mr. Kierstead states. If reactor turns or layers are short-circuited within the reactor, they act as secondaries in a transformer and the currents in the two circuits are inversely in proportion to the number of turns in these circuits. Therefore, the heating due to the increased currents in the short-circuited sections will make itself manifest in a very short time and greatly to the detriment of the reactor.

Mr. Kierstead attaches great importance to the absolute fire-proof quality of the insulation upon the reactor conductor. He gives data of tests carried up to 350 deg. cent. without any distress of the asbestos insulation.

However, the limitation of an arrangement as Mr. Kierstead describes it is not the absolute fire-proof construction but the fact that the temperature coefficients of expansion between copper and concrete are so greatly different and the temperature stresses caused by the copper in the concrete so out of proportion that cracking of the concrete starts long before any shortcomings of the insulation becomes dangerous.

We have in operation throughout the country over 2500 reactors with all kinds of fibrous insulations and do not seem to have trouble on account of the kind of insulation over the conductor.

I do agree with the statement that the insulation should be mechanically strong to be able to withstand injury. From time to time, we have received complaints from one or another of our clients that suddenly a reactor started to rattle. Investigation proved that in practically all cases the trouble was due to foreign bodies becoming lodged in the reactors.

Thus, it would seem that as long as the reactor conductor insulation has ample dielectric and mechanical strength it is only a convenience of design or cost as to what kind should be used.

A. E. Kennelly: In connection with Mr. Kierstead's paper, it may be worth while to point out what is certainly known although not perhaps very generally known, that in a uniform magnetic field, parallel lines of magnetic force so to speak, a small

1. A. I. E. E. JOURNAL, February, 1926, p. 137.

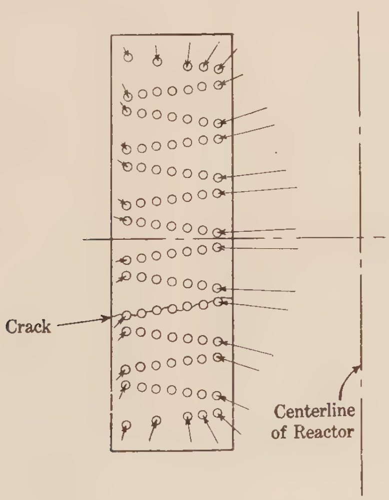
sphere of iron or steel is not subjected to any mechanical pull. That is contrary to popular belief on that subject. If a small sphere of steel is supported in a uniform magnetic field, no matter how strong the field, it will pull one way as much as the other. But if the magnetic field, instead of being uniform, is divergent in one direction, or convergent in the other, then the ball of iron or steel inserted in the field will be pulled in the direction of convergence and the pull is proportional to the flux density and to convergence. Mathematically it may be expressed as proportional to $B \cdot \frac{d\,B}{d\,c}$

W. W. Lewis: Reactors as well as other apparatus have their share of failures; some of these in the past have been due to mechanical weakness, others have been attributed to high voltage and others to so-called foreign metallic material.

The theory of foreign material has been amply substantiated in practise. In one installation 9 reactor failures occurred. Inspection after the first and last of these disclosed nails lying across some of the turns. In two other cases the reactors had been previously damaged. In the five other cases no definite cause was found for the failure. After the first failure, however, a quantity of bolts, nuts, washers and nails was cleaned out of the reactors. It may well be that some of these articles were missed in the inspection as indicated by the nail found after the last failure.

It seems obvious that live conductors so closely spaced as in reactors, are a menace to operation if left uninsulated and Mr. Kierstead is to be commended for removing this source of trouble.

F. H. Kierstead: Mr. Oesterreicher is correct in his statement that when the conductor is raised to 350 deg. cent. the concrete may crack, but his inference that failure of the reactor follows this cracking is not correct. The magnetic field of the reactor exerts a force on the winding that is transmitted as a compressive force on the concrete which forces the cracked surface closer together as is indicated in the illustration shown



Section through a Reactor, Showing How the Magnetic Force Exerts a Compressive Stress Upon the Concrete

herewith. Because of this fact the reactor continues to perform its function just as well after the concrete has cracked as before. The principle involved here is very much the same as that in a reenforced concrete building. The concrete of a building cracks due to expansion and contraction but it causes no concern because its compressive strength is not impaired by the cracks while the steel reenforcing resists the tension forces. The two cases are similar except that in the reactor the forces are all compressive and thus the reenforcing steel is not required.

These statements have been verified by twelve years of experience with this type of reactor in service.

TEMPERATURE RISE AND LOSSES IN STRUCTURAL-STEEL MEMBERS EXPOSED TO THE FIELDS FROM A-C. CONDUCTORS[1]

(Schurig and Kuehni)

New York, N. Y., February 9, 1926.

H. C. Forbes: Engineers who have been concerned with the layout of isolated-phase generating stations will be especially interested in the paper of Mr. Schurig and Mr. Kuehni. In general, this type of station construction is likely to lead to a condition such that heavy currents will be flowing through a bus bar which may be in fairly close proximity to the steel work of the station while the return circuit for this current is comparatively remote.

Some tests were made by The New York Edison Company to determine how serious the heating might be under these conditions and to ascertain what measures might be taken to reduce it. The results of these tests are too voluminous to be presented in their entirety, but it may be of interest to discuss some of them and to note the agreement with those given in the paper.

The structure tested was a rectangular steel loop about 6 in. by 10 in. Tests were made with the current-carrying conductor passing through the closed loop and then were repeated with one side of the loop removed and finally with the conductor passing at right angles to a single member of the loop.

It was found that with the conductor approximately 30 ft. from the steel work, the loss in the case of the single member was about 60 per cent of the loss under similar conditions with the loop completely closed. If the steel loop were larger, this difference would undoubtedly become less pronounced and for the construction used in most generating stations, the losses and resultant heating would be largely independent of whether or not the steel work formed a closed loop around the conductor. The temperature rise in the members would depend chiefly upon the proximity of the conductor, and the value of the current flowing.

Most of our tests were made at 60 cycles, but a few comparative tests were made at both 25 and 60 cycles. These gave a ratio of temperature rise of about 1.7 which I would consider a very good check on the value of 1.6 as given in the paper, particularly in view of the limited number of our own tests covering this point.

It was realized that the losses might be reduced by putting short-circuited copper turns around the steel members and tests showed that such a loop, when placed around the steel member at the point nearest the conductor, reduced the losses by 40 per cent in the case of a single steel member at right angles to the conductor and 60 per cent in the case of the closed steel frame. The use of more short-circuited loops than one at the point nearest to the conductor gave but little further reduction in the losses.

It appears from the tests which have been made that some caution should be observed in station design to avoid heating in the steel work and the paper which has been presented will serve as a very valuable guide. However, if care is taken to place conductors which are to carry heavy currents, say from 2500 to 4000 amperes at a distance of 2.5 ft. or more from the steel work, the heating will not ordinarily be serious and it is doubtful if the use of short-circuited copper loops would be justified.

A. E. Kennelly: We know that such physical conditions as described in this paper are very complicated and that it is very difficult to find a simple formula to cover a great range of such multitudinous conditions, but the practical way in which the results are tabulated and indicated seems of great value.

O. R. Schurig: I agree with Mr. Forbes that for spacings

1. Abridgment, A. I. E. E. Journal, May, 1926, p. 446.

as large as 2.5 ft. between conductor and iron members crossing the conductor the temperature rise in the iron may be expected to be only a few degrees for currents of the order of 3000 or 4000 amperes even if the return conductors are quite remote as in isolated-phase construction. That follows from the curves shown in the paper and there is good agreement on this point as well as on the others brought out by Mr. Forbes. Also let me say that it would help a great deal if data obtained by the operating companies could be published in the discussion of this paper or in separate papers. Doubtless a good deal of the work we did could have been saved if the data and experience of other investigators had been available. We certainly hope such information will be published.

We agree with Professor Kennelly that the calculations from the dimensions and physical constants are very complicated and probably not practical at the present stage. However, efforts would doubtless be productive of good results in the course of time. This problem may be a good one for some of the college research laboratories

NO-LOAD COPPER EDDY-CURRENT LOSSES[1]

(Spooner)

New York, N. Y., February 9, 1926

W. J. Foster: I am interested in this paper on the eddy-currents that exist in the copper on open circuit. A very easy way of determining these losses is to make a core-loss test before the machine is wound. Sometimes it interferes with production if a commercial machine is used. Occasionally it happens that a test has to be made at the factory on a machine which is to be shipped that involves knocking it down. In such a case, the core loss can be run off with the machine completely assembled, then after the winding is removed from the armature, it can be repeated.

I notice the author shows reasons why eddy losses exist in the slot, the cross fluxes changing as the rotor advances, etc. There are also conditions at the head of the armature due to the fringing of the flux that are responsible for some losses.

I remember in the case of a few machines many years ago learning something about how to sectionalize conductors by making use of different windings in the same machine, and finding quite a difference in the open-circuit core loss. Possibly others have had similar experiences.

In the matter of determining the losses, as Mr. Dawson and Mr. Barns have described, I believe their method to be about the only feasible method for certain large enclosed machines. However, we must look out for a number of things;—such as the specific gravity of the air. There is the matter of radiation. If it is a very high-speed machine, occupying small space, probably we can entirely neglect the heat that passes off by radiation, but in the case of slower-speed machines that occupy large space and have very large surfaces, some allowance should be made.

P. L. Alger (communicated after adjournment): It has been my opinion for some time that a large part of the observed core loss in a squirrel-cage induction motor is due to circulating currents in the squirrel-cage bars caused by the pulsations of flux in the rotor teeth. These pulsations are due to the variations of reluctance caused by the stator teeth, and are especially large when open slots are used in the stator. Also, these pulsations in the rotor teeth are very large when the ratio of rotor to stator teeth much exceeds unity, they are negligible when the ratio of slots is nearly equal to one, and they are fairly large when the ratio is considerably less than unity, but greater than one-half.

As I understand it, Mr. Spooner now suggests that the loss due to these pulsations of flux in the rotor teeth is not so much due to the circulating currents induced in the winding as to the eddy-current losses produced by the flux forced across the slots as a result of saturation of the teeth. Of course, the flux across the rotor slots is the same when a given number of ampere-turns are present, whether due to current in the rotor bars, or due to saturation in the rotor teeth, other things being equal. Thus, whether the pulsation of reluctance, due to the stator teeth, is counterbalanced by eddy currents and saturation ampere-turns produced in the teeth, as is the case with an open-circuited rotor winding, or is counterbalanced by the ampere-turns of a current induced in the squirrel-cage bars, the same eddy-current loss in the copper should result. But, in the former case, the ampere-turns in the rotor teeth are produced as a result of flux pulsations in the teeth, and these pulsations must be quite large to make many ampere-turns due to saturation. And, in the other case, the ampere-turns in the squirrel-cage winding can be produced by only a small change in flux, corresponding to the voltage required to supply the impedance drop of the winding. Therefore, in the former case, the flux pulsations in the rotor are large, the ampere-turn pulsations in the rotor teeth are not large, and the reflected pulsations of flux in the stator teeth are small; while, in the latter case, the flux pulsations in the rotor teeth are small, the ampere-turn pulsations in the rotor winding are large, and the reflected flux pulsations in the stator teeth are large.

From all this, in the case of a squirrel-cage motor with straight slots and considerably more squirrel-cage bars than stator slots, there can be a very small loss of the type described by Mr. Spooner, as the saturation ampere-turns in the rotor teeth are nearly constant, except for a slip-frequency variation. Therefore, in such cases, one ought to be able to calculate the tooth-frequency core loss as the sum of the pole-face loss, the copper loss in the rotor bars due to the induced currents based on the high-frequency bar resistance, and the flux pulsation loss produced in the stator as a result of the induced rotor currents. Hence, I came to the conclusion that Mr. Spooner's theory does not account for the losses in the ordinary squirrel-cage induction motor with straight slots, and, if he obtains numerical agreement between his calculations and test results, this agreement must be due in some measure to chance.

The foregoing remarks are not intended as a criticism of the paper, but as giving a line of reasoning parallel to Mr. Spooner's which should bring from him some interesting additional ideas. As far as slip-ring induction motors and direct-current machines are concerned, I think Mr. Spooner's theory should give a sound basis for core-loss calculations. It is interesting in this connection to note that, on the basis of Mr. Spooner's ideas, by using a high-grade steel in a d-c. machine, a greater core loss may be obtained than with a low-grade steel, as the extra saturation ampere-turns may cause more losses in the winding than are due to the saving in iron loss itself. On this basis, by subdividing the winding to avoid eddy currents, it should be possible to use a better grade of steel, with the result that a double gain in losses can be secured.

T. Spooner: Referring to Mr. Foster's remarks, we have tested a number of experimental and commercial machines, both d-c. and a-c., according to the method suggested by him, namely, with the windings in position in the slots and with the windings removed. The differences in losses caused by the eddy currents in the copper began to be appreciable at about 70 kilolines per sq. in. mean-tooth induction for induction motors and at about 120 kilolines per sq. in. for salient-pole machines. Often the test losses check the calculated losses quite closely, but sometimes there are rather wide differences. For small-diameter machines where there is considerable tooth taper, it is sometimes difficult to estimate accurately the slot leakage fluxes. This is perhaps one of the chief causes of the observed discrepancies.

We have made no investigation of losses caused by leakage fluxes in the neighborhood of the end windings.

1. A. I. E. E. Journal, March, 1926, p. 264.

Because of the following considerations, I am unable to agree with Mr. Alger's line of reasoning in connection with the eddy-current losses in the rotor bars of squirrel-cage induction motors. In other words, I am still convinced that there exist eddy-current losses in the squirrel-cage bars, after connecting the end rings, which are equal to or greater than those which exist with the bars open-circuited.

Suppose we consider two adjacent teeth, No. 1 tooth having a smaller air-gap reluctance than No. 2 tooth at a given instant. Now, with the bars open-circuited, flux will flow across the slot through the bar from tooth No. 2 to tooth No. 1, giving radial and tangential components of leakage flux. If now the bars are short-circuited, sufficient current will flow in them to bring the mean flux in tooth No. 2 nearly up to that in No. 1. Since the fluxes in the two teeth are practically equal but the air-gap for one of these is less than for the other, the m. m. f. acting on tooth No. 2 must be greater than that acting on No. 1. In other words, the current in the bars will decrease the m. m. f. acting on tooth No. 1 and increase the m. m. f. acting on tooth No. 2. The tangential slot-leakage flux should therefore be increased toward the top of the slot and decreased toward the bottom, the total remaining about constant. At the same time the radial slot leakage flux will be decreased on the side toward tooth No. 1 and increased toward tooth No. 2.

High-frequency circulating currents in squirrel-cage windings, assuming an effective resistance as calculated by Field's formula, do not, in the cases which I have observed, account for the increased losses due to the presence of the copper bars unless the pulsation losses in the stator teeth due to the high-frequency circulating currents in the rotor windings are much greater than those which existed in the rotor teeth before closing the squirrel-cage windings. This seems improbable since the pulsation losses with closed squirrel-cage windings show no tendency toward decreasing as the induction increases due to tooth saturation, as would be the case if they were due to high-frequency iron losses in the stator teeth.

Mr. Alger's point concerning the danger of using high-silicon steel for the cores of machines operating at high-tooth inductions is well taken. Since at high inductions the permeability of 4 per cent silicon steel may be from ½ to 1/3 of that of low-silicon steel, the slot-leakage fluxes will be greatly increased for the former. Since the eddy-current losses increase as the square of the slot-leakage fluxes, the substitution of high- for low-silicon steel may increase very considerably the copper eddy losses.

The remedy is, of course, a greater subdivision of the copper, as suggested by Mr. Alger.

HEAVISIDE'S PROOF OF HIS EXPANSION THEOREM[1]

(M. S. Vallarta)

New York, N. Y., February 11, 1926

J. J. Smith: I should like to refer to the paragraph third from the end of Mr. Vallarta's paper in which he states that Heaviside gave another alternative proof of his Expansion Formula. This is given in Heaviside's Electrical Papers, Vol. II, p. 226, in a footnote. As this seems to be another very important way of proving the expansion theorem, I shall take the liberty of quoting it in full, as follows:

Let

$$C = \frac{f(p_0)}{\phi(p_0)} E \tag{1}$$

be the differential equation connecting C with E where p_0 stands for d/dt and $\phi(p) = 0$ is the determinantal equation of the system, that is, $\phi(p)$ may be either the characteristic function in fully developed form, or the same multiplied by any function which does not conflict with its use in the determinantal equation. Then we have by the algebraical theorem:

$$\frac{1}{\phi(p_0)} = \sum \frac{1}{(p_0 - p)\,\phi'} \tag{2}$$

where ϕ' means $d\phi/dp$, and the summation includes all the roots of $\phi(p) = 0$. Therefore, by (1), using (2) and integrating:

$$C = f(p_0) \sum \frac{E}{(p_0 - p)\,\phi'} = E f(p_0) \sum \frac{e^{pt} - 1}{p\,\phi'} \tag{3}$$

E being zero before and constant after $t = 0$. But also by (2):

$$\frac{1}{\phi_0} = \sum \frac{1}{-p\;\phi'} \tag{4}$$

where ϕ_0 means ϕ with $p_0 = 0$, so that (3) becomes:

$$C = E f(p_0) \frac{1}{\phi_0} + E f(p_0) \sum \frac{e^{pt}}{p\,\phi'} \tag{5}$$

Now, perform the operations indicated by $f(p_0)$ and we get:

$$C = E \frac{f_0}{\phi_0} + E \sum \frac{f(p)}{p\,\phi'} e^{pt} \tag{6}$$

where f_0 means f with $p_0 = 0$. (See also the investigation at the end of the (later) paper on "Resistance and Conductance Operators.")

(6) is the form of the expansion theorem given by Heaviside in his Electromagnetic Theory, Vol. II, p. 135, a modified form of which is given on p. 127.

On going through the second volume of the Electromagnetic Theory, it is, I think, fairly evident that Heaviside used the above conception of the expansion theorem quite freely. For instance, on p. 88 he solves the problem of voltage applied at one end ($x = 0$) to a cable of length l which is grounded at the other ($x = l$) and for which the well-known formula is:

$$V = \frac{\sinh q\,(l - x)}{\sinh q\,l} E$$

By expanding

$$\frac{q\,l}{\sinh q\,l} = 1 - \frac{2}{1 + \left(\frac{\pi}{q\,l}\right)^2} + \frac{2}{1 + \left(\frac{2\,\pi}{q\,l}\right)^2} - \frac{2}{1 + \left(\frac{3\,\pi}{q\,l}\right)^2} \ldots$$

where

$$q = \sqrt{C\,R\,\frac{d}{d\,t}}$$

and then identifying

$$\frac{1}{1 + \dfrac{n^2\,\pi^2}{R\,C\,l^2\,\dfrac{d}{d\,t}}} \text{ with } e^{-\frac{n^2\pi^2 t}{RSl^2}}$$

the solution of the problem is readily obtained.

If his work in this example is carefully followed out it will be found that he is doing nothing but developing the various steps in the expansion theorem given in the footnote in his Electrical Papers, p. 226.

There are two fundamental concepts back of this derivation which it may be interesting to examine. Writing (1) in the form:

$$\left(A_n \frac{d^n}{d\,t^n} + A_{n-1} \frac{d^{n-1}}{d\,t^{n-1}} + \ldots\ldots + A_1 \frac{d}{d\,t} + A_0\right) C = f(p_0)\,E \tag{7}$$

where the actual value of $\phi(p_0)$ is inserted, it may be seen that this is a linear differential equation of the nth order for C. Now it is known that the general solution of this equation is:

$$C = B_1\,e^{p_1 t} + B_2\,e^{p_2 t} + \ldots\ldots + B_n\,e^{p_n t} + \frac{f(p_0)_{\,p_0 = 0}\,E}{A_0} \tag{8}$$

1. A. I. E. E. Journal, April, 1926, p. 383.

where $p_1, p_2 \ldots \ldots p_n$ are the roots of the equation

$$A_n p^n + A_{n-1} p^{n-1} + \ldots \ldots + A_1 p + A_0 = 0$$

Each term $e^{p_r t}$ is a solution of the equation

$$\left(\frac{d}{d\,t} - p_r \right) y = 0$$

We are thus lead to expect that the solution of a linear differential equation of the nth order can be made to depend upon the solution of n linear equations of the first order, and if a comparison is made of equations (**1**) and (**3**) it will be seen that the equation of the nth order in (**1**) has been transformed into n equations of the first order in (**3**) by means of a partial fraction expansion.

The second point to notice is that nowhere in the above proof does Heaviside use the property $C = 0$ when $t = 0$. What he does postulate is that E is zero before and constant after $t = 0$. It is under this hypothesis that in order to find the value of $\frac{1}{p_0 - p}$ he assumes it to be say y, then

$$(p_0 - p) \; y = E$$

Or

$$\left(\frac{d}{d\,t} - p \right) y = E$$

giving

$$y = i_0 \, e^{+p(t - t_0)} + \frac{E\,(e^{pt} - 1)}{p}$$

Now in all practical problems the real part of p is negative, corresponding to circuits with resistance in which energy is dissipated; hence, whatever current may have existed at the instant $t_0 < 0$, where the actual value of t_0 may be made as large as we please, it will have become negligible by the time $t = 0$. Hence, the effect produced by the applied voltage E is contained wholly in the second term, giving

$$y = 0 \qquad t < 0$$

$$y = \frac{E\,(e^{pt} - 1)}{p} \qquad t > 0$$

Or, if we wish to put it another way, the y caused by E applied at $t = 0$ is given by this term, and the $i_0\, e^{p(t - t_0)}$ part is due to another cause. This is not the way in which Heaviside makes this particular step but the results are the same.

Whatever way we chose to look at it, the facts are that by using this substitution in (**3**) as shown, and completing the solution as in (**6**), we get the solution of (**1**), corresponding to the system (assumed to be a dissipative one) represented by (**1**) being at rest, and having been at rest for a very long time prior to $t = 0$. We have thus used the one condition

$$E = 0 \qquad t < 0$$

$$E = E \text{ constant} \qquad t > 0$$

to supplant the n terminal conditions which would be normally required to determine the constants in the solution of (**1**) or (**7**). The economy in such a reduction of terminal conditions should be apparent. The economy becomes more apparent when applied to problems in long transmission lines where an infinite number of terminal conditions arise in certain methods of obtaining the solution.

I presume the reason Mr. Vallarta did not discuss Heaviside's second derivation referred to above is that it involves so-called operational mathematics, and operational methods have been looked upon with disfavor by mathematicians for many years as being lacking in rigor, which may or may not be true. I like to think, however, that between the operational mathematics and the conventional pure mathematics there must be some common ground on which they can both meet together by a little give-and-take on both sides. I have published two papers in the *Journal* of the Franklin Institute with this end in view, one in June, 1923, and the other as a serial in October, November and December, 1925. In these papers the ideas given above are developed more fully. The interesting part, however, is that although Heaviside, as far as I am aware, uses his expansion theorem only in continuous systems for one coordinate in addition to the time, such an attempted development of a common ground between pure and operational mathematics has lead to a method of solution for two- and three-dimensional problems such as occur in the flow of heat, and in addition to the solution of potential problems in electrostatics in which no time factor appears. These results come from simple extensions of the development of the expansion theorem given above, which then becomes a particular expansion theorem in a great class of expansion theorems. Reference must be made to my paper for details. However, with Mr Vallarta I join in a plea for greater study of the works of Heaviside and for the development of both his ideas and the concepts of pure mathematics to the point where they will both merge into one as I have not the slightest doubt they should.

M. S. Vallarta: In his valuable discussion Mr. J. J. Smith has already given Heaviside's second proof of the Expansion Theorem, to be found in the second volume of his "Electrical Papers" (l. c. footnote 19 of the writer's paper.) The writer did not feel that a complete account of this second method of proof was necessary partly because it has already been discussed rather thoroughly elsewhere (see for example reference 9 in the writer's paper), but mostly because it is not quite so illuminating, or important from a physical standpoint, as the first method of proof based on the conjugate theorem.

Mr. Smith raises an interesting question when he speaks of operational calculus and its relation to the Expansion Theorem. As shown in the paper, operational methods are not required to establish the Expansion Theorem in the case of no null and no repeated roots of the determinantal equation, but the use of such methods really simplifies matters considerably in this exceptional case. For purposes of technical applications, however, the writer feels that both may properly be kept separate. That operational calculus can be rigorized if the proper tools and methods of attack are used has been shown by Wiener ("The Operational Calculus" forthcoming in the *Mathematische Annalen*) and Carson (see the Bell Technical *Journal* for 1925 and 1926). Once operational calculus is rightly understood it may be applied confidently not only to engineering problems, but also to problems in pure mathematical physics where less powerful methods break down completely. As a most advanced example of this type of problems, reference is made to a paper by Born and Wiener, (*Journal* of Mathematics and Physics of M. I. T., Vol. 5, p. 84, Feb. 1926) to quote but a single example.

The great importance of the conjugate theorem has been very recently recognized by K. W. Wagner ("Der Satz von der wechselseitigen Energie" *Elektrische Nachrichten-Technik*, Vol. 2, p. 376, Nov. 1925) who also gave in this article Heaviside's first method of proof of the Expansion Theorem. This and the writer's paper were written approximately at the same time (Wagner's paper was received for publication on Nov. 9, 1925; the author's paper on Dec. 1, 1925). The present writer is glad to add this interesting reference to the list already given in the paper.

THE USE OF VIBRATION INSTRUMENTS ON ELECTRICAL MACHINERY[1]

(Ormondroyd)

New York, N. Y., February 11, 1926

W. B. Creagmile: Mr. Ormondroyd has mentioned a vibrating-reed type of instrument with one reed. The common use of vibrating-reed instruments having a series of tuned reeds along a marked scale, to measure revolutions per minute

1. A. I. E. E, Journal, April, 1926, p. 330.

and a-c. frequency, is not mentioned in the paper. The reeds of the tachometer pick up mechanical vibration from the machine to which the instrument is attached. In the frequency meter, the reeds are set in vibration by alternating current flowing through an electromagnet placed in series with resistance across the mains.

The amplitude of vibration of any reed is dependent upon the amount of vibration of the machine to which the tachometer is attached, or the voltage of the line to which the frequency meter is connected. However, speed or frequency is not read by observing the amplitude of vibration of any particular reed, but by noting which reed is in vibration. Hence, we may say that the indications of speed and frequency given by the vibrating-reed tachometer and vibrating-reed frequency meter are entirely independent of the exact amount of vibration of the machine under test or of voltage of the a-c. line.

J. Ormondroyd: On the second page of the paper, the first sentence in the section on "The Vibrating Reed" makes brief mention of the two common uses of "tuned" reeds. Since the reed tachometers and electrical frequency meters are not used primarily to study vibration, no further mention is made of them.

The amplitude of motion at the end of a reed in a Frahm tachometer can be represented by equation (**15**) if

$$M = M + \frac{m}{4}$$

as in equation (**16**). This equation shows that the amplitude on any reed will be proportional to the impressed amplitude. But it also depends on the dynamic magnification which is a function of the frequency. Fig. 11c shows the relationship between reed-vibration amplitude and impressed vibration.

The reed which happens to be at or near resonance with the impressed frequency will have its motion magnified beyond all proportion to the magnification which the other reeds experience. The magnification at resonance is inversely proportional to the damping factor C as can be seen in Fig. 11c where the effect of two different values of C is shown. Putting $\frac{\omega}{\omega_c} = 1$, in equation (**15**) this is shown very clearly.

The speed or frequency is read by observing which reed has the greatest amplitude. The neighboring reeds usually show some smaller amplitude while the more distant reeds have no apparent motion.

In a sense the indications of speed are independent of the exact amount of the impressed vibration. This statement breaks down at the limit where the exact amount becomes zero. If turbine manufacturers could reach their ideal of perfectly balanced spindles and field-rotors the reed tachometers would become useless.

RATING OF HEATING ELEMENTS FOR ELECTRIC FURNACES[1]

(Keene and Luke)

New York, N. Y., February 11, 1926

G. E. Luke: The equations for heat loss as given in this paper are only approximate. The heat liberated by convection varies to some extent with the position of the resistor. Its variation with temperature rise to the 1.20 power is only empirically true, but it seems to hold over a rather wide range of size and temperature. Fortunately, the rate of loss by convection is a small percentage of the total so that it does not have to be so accurately known. The accuracy of the Stefan-Boltzmann equation for radiation depends upon the correctness of the coefficient of emissivity (e). This value (e) is not constant but changes somewhat with temperature. For practical purposes it can be considered as a constant without great error.

1. A. I. E. E. Journal, March, 1926, p. 222.

Although considerable data are published regarding the rate of heat transfer from high-temperature conductors, yet few are available as to the reduction in this loss due to the proximity of other parallel conductors. At first the method of calculation as shown on Fig. 3 was used. It was recognized that this method was not rigidly correct since the intensity of the heat radiation from a point on a plane surface in any direction is proportional to the cosine of the angle that direction makes with the perpendicular. Nevertheless the approximate method gave results within 2 to 3 per cent of the true loss as determined experimentally.

It is hoped that this paper will show the fallacy of designing resistors according to the constant-current-density method or the constant-surface-loss method. Figs. 5 and 6 show that the possible rating depends largely upon the resistor arrangement.

OPERATING PERFORMANCE OF A PETERSEN EARTH COIL-II[1]

(Oliver and Eberhardt)

New York, N. Y., February 9, 1926

L. P. Ferris: I wish to ask what was the condition of the coil as regards tuning during the period covered by this paper? Was it the same or different from the tuning employed during the period covered by the authors' previous paper on this subject? If the coil remained in the condition of tuning mentioned in the previous paper, overtuned by some 23 per cent., perhaps that will explain to some extent why the coil failed to prevent the tripping of the line switch in some of those fifteen cases listed in Table I. Under this detuned condition, the coil does not limit the fault current to as low a value as it would if it were tuned more exactly. With 23 per cent. overtuning (*i. e.*, with 1207 ohms reactance), the measurements reported in Mr. Lewis' paper of 1923 indicate a fault current of about 4.8 amperes, whereas the same paper gives measured currents of approximately 2.4 amperes for the coil setting nearest resonance (982 ohms). It is conceivable that, under some fault conditions, the arc might be maintained if the current were not reduced below the first figure, but would be extinguished if the current were limited to the smaller value corresponding to exact tuning. Perhaps Messrs. Oliver and Eberhardt could say how large a factor this detuning might be in accounting for some of these fifteen cases? As brought out in the discussion of the earlier papers, it would seem desirable if the coil were operated slightly detuned, that it be operated somewhat undertuned rather than overtuned, although the direction in which it deviates from the exact tuning would not seem to affect its ability to quench an arc.

W. W. Lewis: In this country the trend of operation away from the isolated neutral and toward the grounded neutral has limited the field of the Petersen coil. Nevertheless, the report of Messrs. Oliver and Eberhardt is valuable in clearly pointing out what can be done with this device under suitable circuit conditions.

In Europe, the tendency has been to design the reactor with an iron core to operate normally off resonance, but to be pulled into resonance by saturation when one conductor becomes grounded. As an alternative, the reactance is designed to be outside a certain band on each side of the resonance condition at all times. Both of these designs are intended to prevent certain overvoltage troubles anticipated when the three poles of an oil circuit breaker do not operate simultaneously. The modified devices have found much favor and have been very successful.

W. W. Eberhardt: I shall answer Mr. Ferris' question by stating that the coil, during the period reported in this paper, was overtuned approximately 23 per cent. Towards the end of the operating period, the coil was slightly undertuned but that was after the end of the lightning season and no operating experience was obtained with the undertuned setting.

1. A. I. E. E. Journal, March 1926, p. 227

ILLUMINATION ITEMS

By the Committee on Production and Application of Light

IN ITS INFANCY

Street lighting has been a problem ever since men began to herd together in cities. At first the problem was solved by each citizen who ventured out at night carrying a lantern or hiring a link boy to carry a torch before him.

This didn't amount to much as protection from highwaymen, although it did help some in getting over, around, or through the mud puddles. During that period the easiest and most popular solution of the street lighting problem was to stay at home after dark.

By and by came oil lamps stuck on poles to help out the hand lanterns. Then gas lamps took the place of oil, and so by degrees we come to our modern age of electric lighting.

It is well within the truth to say that even in America street lighting is still in a primitive stage. We have of course our "White Way" in every city of any importance, but once outside this area the streets are often dismal and dangerous after dark. The average community seems to spend just enough on street lighting to make the darkness more confusing. There is a popular notion that street illumination costs much money, but the latest investigation shows that per capita cost is only about 75 cents a year.

Scientific and adequate street lighting is a social question of paramount importance in the modern world.

First of all we have the fact of vastly accelerated out-of-door movement among all classes of people. Shut in by day, the masses and classes alike are impelled to stir abroad at night. In the theatre and shopping district, it has become the recognized practise to make the streets as light as day. What the community fails to furnish, the stores and places of amusement make up as part of their sales and advertising budget.

Among many others there are three reasons why every city, town, and many country roads, must, from now on, be properly lighted.

First the safety, happiness and comfort of all the people demand it. Second, the enormous increase in power transportation brings us to the point where traffic growth must cease unless folks can see where they are going. This refers to pedestrians quite as much as to those in automobiles, busses and street cars. Third, according to an ancient scripture, where the carcass is, the birds will gather together. With the streets thronged at night at the centers, it means that the home streets, roads and byways will all have belated travelers at night. This brings the hold-up man and other criminals to their harvest. Good street-lighting is second only to a good police force as a crime deterrent. Men love darkness rather than light when their deeds are evil. Crime diminishes as light increases.

Recognizing the great social value of good street-lighting, the scientific and engineering resources of the leading lighting laboratories have been directed towards a solution of this problem with extraordinary success. We have the lamps and the electric energy and we know how to use both to the best advantage in street-lighting. When the people wake up to the necessity of proper street lighting, half the job will have been done.—*Light*, March 1926.

NATURAL LIGHTING

Primitive man, during many ages, found daylight ample and satisfying to all his needs. His simple arts were carried on in the open and if the glare of the midday sun was objectionable he sought the shade of the trees. As arts and society became more complex, housing became necessary, and this created the problem of providing adequate indoor lighting. Artificial sources were developed and electric lighting has now reached such a stage of perfection that the cost of natural, as compared with that of artificial light, has become a matter of considerable interest.

Nevertheless, natural light still has its place in industries and homes, and it will still continue to hold this place for the following reasons:

1. It is ample. In our latitude the direct solar thermal energy at noon on a clear day is close to 100 kilowatts per square dekameter, (slightly more than 1000 square feet) or sufficient to maintain 2500 forty-watt lamps, if we could utilize it, which, in the future, someone may learn to do.
2. It never fails. The sun is always shining.
3. It is the kind of light to which the human eye is best adapted, and that which artificial light tries to imitate.

An objection to natural light is that it varies in intensity. Dr. Abbot's studies indicate a variation of about one per cent on each side of the mean in recent years. This is masked, however, by a variation of ± 3.5 per cent due to the varying distance of the earth from the sun. Furthermore, the percentage of solar energy transmitted by the earth's atmosphere varies from day to day and from hour to hour, even when there are no clouds. With clouds completely covering the sky, the diffused solar energy received on a horizontal surface is about one-fourth what it is in the absence of clouds. However, even in cloudy weather, natural lighting is ample for out-door operations except during rainfall, when most out-door work ceases. In the process of evolution the human eye has learned to adapt itself without discomfort to the intense light at midday in summer and to the feeble light of twilight, or a range of intensity from 10,000 to 30 foot-candles.—*Trans. I. E. S.*

The monument erected on the site of the original laboratory of Thomas A. Edison, at Menlo Park, N. J., will hereafter be flood-lighted so as to be visible from the trains of the Pennsylvania Railroad as well as from the Lincoln Highway.

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Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

Regional Meeting at Niagara Falls May 26-28

A program of unusual interest has been arranged for the Regional Meeting which will be held at the Niagara Hotel, Niagara Falls, N. Y., May 26-28, under the direction of the Northeastern District of the Institute. The technical sessions will include a symposium on measurement of dielectric power factor, papers on transmission, tests of hydroelectric units, rectifiers, transformer design, polarization of radio waves, armature reactance, magnetic-flux measurements, current transformers, supervisory control, fire protection for generators, etc. A list of the technical papers was published in the Journal for April 1926, page 391, and a complete program will be distributed by mail prior to the meeting.

One paper not included in previous announcements but to be presented at the meeting is that of T Spooner on "Current Transformers with Nickel-Iron Cores;" also there will be a short talk on *The Calibration of Lichtenberg Figures* by K. B. McEachron of the General Electric Company.

For this meeting, a number of delightful entertainment features have been arranged. There will be a boat trip on Lake Ontario, with dancing on boat; also a scenic and inspection trip through the Gorge, and a special illumination of the Falls, a convention dinner, and two attractive lectures.

Ladies are cordially invited and special arrangements have been made for their enjoyment.

The steamer trip on Lake Ontario will be made on Wednesday evening, May 26. The boat will be boarded at Lewiston and a delightful trip under a full moon is promised. Music will be furnished by a good orchestra and dancing may be enjoyed by all who desire it.

A trip to the Niagara Gorge will be made on Thursday afternoon when the marvelous rapids and whirlpool may be seen. Stops will be made at points of scenic interest and at the power plants on both sides of the ravine, and there will be guides ready to take groups through the plants.

On Thursday evening, the Convention dinner will be held in the Niagara Hotel and a number of Institute officers will speak briefly, including President M. I, Pupin, E. D. Adams, C. C. Chesney, Guiseppe Faccioli, H. M. Hobart and others.

Following the dinner a lecture, with interesting demonstrations on "Modern Reproduction of Sound," will be delivered by L. T. Robinson.

The special illumination of Niagara Falls, which is planned for Thursday night, will be a spectacle of great beauty. The Falls will be bathed in light of changing forms and colors.

A piano recital by Vladimir Karapetoff, together with an interesting interpretation of the music played, is planned for Friday evening as one of the enjoyable events of the meeting.

The first exhibition of the new film of the Niagara Falls Power Company will be given if possible Friday evening in connection with a lecture on the possible future power and scenic developments at the Falls, by George S. Anderson of the Niagara Falls Power Co.

Reduced Railroad Fares

Reduced railroad rates, under the certificate plan, have been granted and every visitor who comes to the meeting by train should get a certificate, if not for his own benefit at least to help others who will want to take advantage of the reduced fare.

Under this plan, every visitor should request a certificate from his local ticket agent when purchasing his ticket to Niagara Falls. If 250 certificates are turned in at the meeting, return tickets over the same route may be had at half-fare rates. There are certain restrictions regarding dates, extra-fare trains, etc.; this information should be obtained from local ticket agents.

Everyone who travels by rail to the meeting *should get a certificate*, whether or not he intends to use it, for as above stated by obtaining a certificate he will help make up the 250 which are necessary to make the reduced fare available to those who wish to take advantage of it.

The Niagara meeting has been planned by the Coordinating Committee of the Northeastern District consisting of H. B. Smith, Chairman, Vice-President in the Northeastern District; A. C. Stevens, Secretary; J. R. Craighead, E. D. Dickinson, J. A. Johnson, A. E. Soderholm and A. W. Underhill, Jr. Local arrangements are being made by a committee of which J. A. Johnson is Chairman.

Madison Regional Meeting May 6-7

Arrangements are completed for the Regional Meeting of the Great Lakes District, to be held in Madison, Wis., at the Hotel Loraine, May 6-7. The program contains technical papers on the subjects of rural electric service, high-voltage cables, interconnected systems, research between colleges and industries and radio receiving circuits. A convention dinner and inspection trips are also scheduled. A complete program was published in the April issue of the Institute's Journal, page 390.

Student Convention at M. I. T. May 7

Plans are practically complete for the Student Convention of the First District of the Institute to be held at Massachusetts Institute of Technology, Cambridge, Mass., on May 7. The tentative program is as follows: In the morning, there will be three or four student papers and discussions. At noon there will

be a luncheon and Counsellor's meeting. In the afternoon inspection trips will be made to Edgar Station, Simplex Wire and Cable Company, a machine-switching telephone exchange and the M. I. T. Laboratories.

A joint banquet with the Boston Section will be held in the evening. Dr. M. I. Pupin, President of the A. I. E. E., will speak on "Science and Engineering." The other speaker of the evening will be Mr. R. E. Doherty, of the General Electric Company.

Stanley A. Tucker, Chairman of the Yale Branch, will preside at the morning session. Prof. H. B. Smith, Vice-President in the First District, will act as toastmaster at the banquet in the evening and is sponsoring the meeting of the Counsellors.

A student committee, of which Stuart John is Chairman, is arranging the meeting with the assistance of Vice-President H. B. Smith and J. W. Kidder, R. D. Booth, W. H. Colburn, H. W. Timbie and H. B. Dwight, all of the Boston Section.

Annual Convention, June 21-25 at White Sulphur Springs

The forty-second Annual Convention, which will be held at *The Greenbrier*, White Sulphur Springs, West Virginia, June 21-25, will be very interesting and enjoyable technically and socially.

In the technical program there will be papers on such subjects as magnetization, remotely-controlled substations, high-speed circuit breakers, electric transients, machine windings, regenerative braking, non-harmonic alternating currents, theory of synchronous machines, heat transfer in machines, etc.

The reports of Institute's Technical Committees will form a major part of the technical sessions. These should be of interest to all, as they are written to describe advances in design and practise in the various fields of electricity.

As a feature of general interest it is planned to have addresses by representatives of the American Engineering Council and the American Engineering Standards Committee. The objects and activities of these organizations will be explained, as well as their relation to the Institute and other electrical organizations.

White Sulphur Springs is an exceptionally attractive location for the Convention and *The Greenbrier* is a magnificent hotel, possessing every comfort and convenience. Among the attractions will be golf, tennis, horseback riding, motoring, sulphur baths, a swimming pool, not to mention the beautiful scenery of the place. All afternoons will be free for recreation.

A complete program will be published in the June issue of the JOURNAL.

A. I. E. E. Directors' Meeting

The regular meeting of the Board of Directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, on Friday, April 9, 1926.

Present: President M. I. Pupin, New York, Past-President Farley Osgood, New York, Vice-Presidents Harold B. Smith, Worcester, Mass.; A. G. Pierce, Cleveland; Managers H. M. Hobart, Schenectady, N. Y.; G. L. Knight, Brooklyn, N. Y.; W. K. Vanderpoel, New York; John B. Whitehead, Baltimore; E. B. Merriam, Schenectady, N. Y.; H. A. Kidder, New York; National Treasurer George A. Hamilton, Elizabeth, N. J.; National Secretary F. L. Hutchinson, New York.

The minutes of the Directors' meeting of February 9, were approved as previously circulated.

The Board ratified the action of the Executive Committee, under date of March 19, in approving applications for student enrolment, election to membership, and transfer from one grade to another.

Reports were presented of meetings of the Board of Examiners held March 8 and April 9, and actions taken at those meetings were approved. Upon the recommendation of the Board of Examiners, the following actions were taken on pending applications: 30 Students were ordered enrolled, 207 applicants were elected to the grade of Associate, 1 applicant was elected to the grade of Member, 1 applicant was elected to the grade of Fellow, 16 applicants were transferred to the grade of Member, 1 applicant was transferred to the grade of Fellow.

The Board ratified the approval by the Finance Committee for payment, of monthly bills amounting to $25,024.05.

Upon recommendation, approved by the Finance Committee, the Board voted to authorize the payment of traveling expenses, at the rate of ten cents per mile one way, of District Secretaries to the Section Delegates Conference at the Annual Convention, each year.

Upon request from the Pittsburgh Section, the Board authorized the extension of the territory of the Pittsburgh Section to include Marion and Harrison Counties, West Virginia.

The Board granted a request of the Portland, Seattle, and Spokane Sections for a readjustment of their boundaries to include territory not previously included in any Section.

Upon the approval of the Committee on Student Branches, the establishment of a Student Branch at Washington and Lee University, Lexington, Virginia, was authorized.

A proposed Uniform Electrical Ordinance and Uniform Statute, recommended by the Electrical Manufacturers Council, was considered and endorsed.

The Secretary announced the receipt of the trust fund for the Lamme Medal, bequeathed to the Institute by the late Benjamin G. Lamme, amounting to $5160 ($6000 less the inheritance tax); the formulation of a plan of procedure for making the award and the preparation of the design for the medal was referred to the Committee on Award of Institute Prizes for consideration and report to the Board of Directors.

The Board voted a gold medal award, in addition to the $100 previously authorized, in connection with the national "Best Paper Prize" recently established, to commence with the year 1926. The matter of design of this medal was referred to the Committee on Award of Institute Prizes.

In accordance with Section 33 of the constitution, the Board ratified the appointment by the President of the Tellers Committee, to report upon the ballots received in connection with the 1926 election of Institute officers, as follows: Messrs. S. P. Grace (Chairman), W. E. Coover, E. S. Holcombe, R. R. Kime, E. F. Thrall, E. F. Watson, and John T. Wells.

The Board confirmed the appointment by the President of Dr. Cary T. Hutchinson to succeed Dr. A. E. Kennelly as an Institute representative on the Engineering Division, National Research Council, and of Mr. Farley Osgood as an Institute representative on the Committee on Electric Power Houses, National Fire Protection Association.

Consideration was given to a request from American Engineering Council, and from the Denver Section of the Institute, that the Board of Directors go on record in approving Federal Bill H. R. 9397 to provide for inventory of water resources in the United States, and the Board voted its endorsement of the bill.

An invitation from the American Academy of Political and Social Science to be represented at the annual meeting, in Philadelphia, May 14-15, of that organization, was accepted, and the President was authorized to appoint delegates to this meeting.

The resignation of Mr. H. P. Gibbs as Local Honorary Secretary of the Institute for India, on account of leaving India, was presented, and upon the recommendation of Mr. Gibbs, Mr. F. W. Willis was appointed to succeed Mr. Gibbs as Local Honorary Secretary for India.

The Board accepted an invitation to appoint three representatives to attend the unveiling of the bust of Eli Whitney at the Hall of Fame, New York University, May 12, and Messrs. H. A. Kidder, G. L. Knight, and W. I. Slichter, were appointed.

Other matters of importance were discussed, reference to which may be found in this and future issues of the JOURNAL.

First Plenary Meeting in United States of the International Electrotechnical Commission April, 13-22, 1926

The first plenary meeting of the International Electrotechnical Commission ever held in the United States opened April 13 and terminated April 22, in the Engineering Societies Building, New York.

More than one hundred delegates, representing most of the European nations and accompanied by about twenty ladies, arrived in New York about noon on April 13, on the Steamship *Andania*, and were met at the pier by a delegation of the official Reception Committee, including Messrs. John W. Lieb, Chairman, Frank W. Smith, C. E. Skinner, P. G. Agnew, F. R. Low, Elihu Thomson, C. O. Mailloux, Clayton H. Sharp, A. E. Kennelly, and C. A. Adams.

The first session, designed for the purpose of extending a welcome to the visitors, was held under the sponsorship of the United States National Committee in the Auditorium of the Engineering Societies Building, on Tuesday evening, April 13. Chairman John W. Lieb, of the Reception Committee, presided, and an address was made by Honorable Herbert Hoover by telephone from Washington, transmitted directly to the audience by amplifiers. Thomas A. Edison, Honorary President of the Reception Committee, sent greetings by telegraph from Florida, and a cablegram was read from the former Premier of Great Britain, Lord Balfour. Dr. Elihu Thomson, Past-President of the I. E. C., welcomed the delegates on behalf of the United States National Committee, and Dr. Howard T. Barnes, President of the Canadian National Committee, extended the greetings of the Dominion. Responses were made for Great Britain by Colonel R. E. Crompton, C. B., Honorary Secretary, I. E. C.; by M. E. Genissieu, of France; A. F. Enstrom, of Sweden; Professor V. List, of Czechoslovakia; Dr. P. Strecker, of Germany. The ceremonies were closed with the address by the President of the I. E. C., Guido Semenza, of Milan, Italy, on "Accomplishments and Aims of the International Electrotechnical Commission."

In a quotation from President Semenza's address, "when we unify nomenclature in electrical science and manufacture, and when we establish unified ratings for machines, then we shall have simplified production," the aims and activities of the I. E. C. are fittingly described. Out of the International Electrical Congress held in St. Louis in 1904 has grown this international standardizing body representing some twenty-four nations and to them has been due much of the international cooperation by which greater uniformity of practise, nomenclature and rating has facilitated international commerce. Through the medium of the U. S. National Committee standards in America have been communicated to the International body and the standardizing bodies here have been made fully acquainted with progress in the international field.

The Reception Committee tendered a luncheon to the visiting delegates at the Hotel Commodore on Wednesday at 12:30. Dr. John W. Lieb presided. Among the speakers were Dr. M. I. Pupin, President A. I. E. E.; Sir Archibald Denny, Dr. Guido Semenza, Dr. Clayton H. Sharp and Dr. C. O. Mailloux.

Numerous inspection trips to points of engineering interest, luncheons, and other events were carried out during the entire stay of the delegates in New York. For the ladies, a special program was arranged by the Entertainment and Hostesses Committees, including motor trips, theatre parties, teas, etc. On Thursday, April 15, a luncheon was tendered, to the chairman and secretaries of the various bodies engaged in standardization in the United States and abroad, by the American Engineering Standards Committee.

On Monday evening, April 19th, a banquet was tendered by the electric light and power companies of New York City to the visiting and American delegates and ladies, about three hundred in number, at the Hotel Astor. Mr. Gano Dunn, Past-President of the American Institute of Electrical Engineers and Chairman of the National Research Council, acted as toastmaster. The speakers were Hon. James J. Walker, Mayor, City of New York, John W. Lieb, Vice President, N. Y. Edison Company, Guido Semenza, President I. E. C., E. Uytborck, Chairman Belgian Delegation, C. Feldmann, President, Dutch Electrotechnical Committee, Domingo Santa Mario, Chili, E. Huber-stockar, Switzerland, and Sir Richard Glazebrook, Great Britain. Professor Lombardi extended an invitation to hold the next meeting in Italy.

On Wednesday evening, the 21st, with the visiting delegates of the I. E. C. as hosts, a banquet was given to the U. S. National Committee, also at Hotel Astor. President Guido Semenza presided. On behalf of the visitors he presented a beautiful statue of Nike, the winged Goddess of Victory. In response, Dr. Clayton H. Sharp, President of the U. S. National Committee thanked the delegates for the emblem of friendship and expressed the hope that this country would again have the privilege of entertaining the commission. Representatives of several of the nations represented expressed their felicitations.

International Electrochemical Commission Delegates' Visit to the White House, Washington, D. C.

A complete list of the delegates from all countries follows:

LIST OF DELEGATES

Signor Guido Semenza, President, I. E. C.
Dr. C. O. Mailloux, E. E., Honorary President, I. E. C.
Col. R. E. Crompton, C. B., R. E., Honorary Secretary, I. E. C.
Mr. C. le Maistre, C. B. E., General Secretary, I. E. C.

Austria:
Herr Bretschneider, Vice-President, Austrian Standards Committee;

Belgium:
E. Uytborck, Secretary, Belgian Electrotechnical Committee;
L. Colson, General Director, Electrical Section, Belgian State Railways;
M. Danly, Société Financière de Transports et d'Entreprises industrielles;
Franz Dupont, Chief Engineer, Ateliers de Construction electrique, Charleroi;
C. Baron Forgeur, Director at Head Office, Ministry of Industry;
M. Victor Lagasse de Locht, Société Générale des Chemins de fer Economiques;

Canada:
James Kynoch, Chief Engineer, Canadian G. E. Co.;
John Murphy, Consulting Engineer, Dominion Government;
H. T. Barnes, President, Canadian National Committee;
I. L. Durley;

Czechoslovakia:
V. List, Chairman, Czechoslovakian Electrotechnical and Standards Committees;
F. Pergler, Czechoslovakian Standards Committee;
B. Rosenbaum, Secretary, Czechoslovakian Standards Committee;

Chili:
Domingo Santa Maria;

France:
G. J. Darrieus, Cie Electromécanique;
J. J. Frick, Société Alsacienne de Constructions Mécaniques;
E. Genissieu, Ing. en chef des Forces Hydraulics et de distribution d'energie au Ministére des Travaux Publics;
P. Girault, Cie. Fr. Thomson-Houston;
E. Roth, Société Alsacienne de Constructions Mécaniques;

Germany:
P. Strecker, President, German Electrotechnical Committee, Professor at Heidelberg;
P. Schirp, Secretary, German Electrotechnical Committee and V.D.E.;
L. Fleischmann, Allgemeine Elektricitas Gesellschaft;
Herr Hochtl, Chief Government Architect;
Dr. M. Kloss, Professor at Charlottenberg;
Oberingenieur A. Maier; German Standards Committee;
Dr. Moldenhauer, Markisches Elektrizitats-Werk;
Dr. Rudenberg, Siemens-Schuckertwerke;
Herr Schlothauer, Counsellor of Commerce;
Herr Schuchardt, Counsellor of Commerce;
Rich. Stern, Rhenania-Ossac Mineraloiwerke;
Herr Stotz, Engineer and Gen. Mgr., Stotz Company;
Director Strehlow;
K. W. Wagner, Office of Engineering Research, Administration of Posts and Telegraphs;
Dr. Kienzle, German Standards Committee;

Great Britain:
Sir Richard Glazebrook, K. C. B., Chairman, British National Committee;
Sir Archibald Denny, Bart., Chairman, British Engineering Standards Association;
L. B. Atkinson, Director, Cable Makers' Association;
C. P. Sparks, C. B. E., Vice-Chairman, British National Committee;
S. C. Bartholomew, General Post Office;
E. G. Batt, General Electric Co.;
W. S. Burge, English Electric Co.;
P. Dunsheath, W. T. Henley's Telegraph Works;
A. R. Everest, British Thomson-Houston Co.;
P. Good, Secretary of the British Delegation;
W. Lee, Silvertown Lubricants, Ltd.;
S. W. Melsom, Callender's Cable & Construction Co.;
A. C. Michie, Consulting Chemist;
R. B. Mitchell, Municipal Electrical Engineer, Glasgow;
A. P. Mossay, Messrs. Mossay & Company;
J. S. Peck, Metropolitan Vickers Electrical Co.;
C. Rodgers, O. B. E., Secretary, British Electrical & Allied Manufacturers' Association;
T. Roles, Municipal Electrical Engineer, Bradford;
P. F. Rowell, Secretary, Institution of Electrical Engineers;
F. Wallis, English Electric Co.;
K. Edgcumbe, Everitt Edgcumbe & Co.;
W. S. Marshall, Shell-Mex., Ltd.;

Holland:
C. Feldmann, President, Dutch Electrotechnical Committee and Professor at the Technical University, Delft;
W. H. Tromp, Secretary, Dutch Electrotechnical Committee;
C. Pot, Director of the Electrotechnical Works, formerly W. Smit & Co., Slikkerveer;
T. Rosskopf, Director of Transformer Works, Nijmegen;
C. Van der Bilt, Professor at the Technical University, Delft;
G. J. Van de Well, Extraordinary member of Patent Service;

Italy:
G. Semenza, President, I. E. C.;
L. Lombardi, President, Italian Electrotechnical Committee and Professor at Technical Engineering College—Rome;
G. Bianchi, Italian State Railways;
Carlo Clerici, Soc. Edison per la Fabbricazione delle lampade Ing. Clerici;
Piero Ferrerio, Società Générales Italiana Edison di Electricci;
Oreste Jacobini, Italian State Railways;
G. Minucciani, Italian State Railways;
E. Morelli, Professor of Electric Machinery Construction at the School of Engineering, Turin;
Ing. Luciano Pello;
Natale Ratti, Riva Company of Milan;
E. Theseider-Dupre, Italian State Railways;
Ingr. R. Vallauri, Professor of Electric Traction at the Milan Technical School;
E. Virgilli, Italian State Railways;

Norway:
E. Heiberg, Director, Norwegian Industrial Standardisation Bureau;

Poland:
C. Daewnowski, Secretary, Polish Electrotechnical Committee;
Mr. Roginski, Secretary, Polish Standards Committee;

Russia:
M. Chatelain, Chairman, Russian Electrotechnical Council, Vice-President, Russian Standards Committee;
Mr. Lapiroff-Scoblo, Russian Standards Committee;
Mr. Papernoff, Secretary, Russian Standards Committee;
Mr. Zischievsky, Russian Standards Committee;

Sweden:
S. Norberg, Vice-President Swedish Electrotechnical Committee and Swedish General Electric Co.;
A. F. Enstrom, President, Swedish Standards Committee;
Mr. Ericson, Secretary, Swedish Electrotechnical Committee;
Amos Kruse, Secretary, Swedish Standards Committee;
Mr. Nordstrom, Swedish Standards Committee;
H. Nystrom, Secretary, Electric Manufacturers Association;
Mr. Osterberg, Asst. Secretary, Swedish Standards Committee;
G. Thielers, Swedish General Electric Co.;

Switzerland:
E. Huber-Stockar, President, Swiss Electrotechnical Committee;
A. Huber-Ruf, Engineer, Brown Boverie Co.;
Charles Burlet, Electrical Engineer, Swiss Federal Railways;
C. Hoenig, Chairman, Swiss Standards Committee;
Hans Max Schindler, Ateliers de Construction, Oerlikon;
Antoine Schrafl, Swiss Federal Railways, (Construction and Working); Paul Thut, Bernese Power Works;

Spain:
Vicente L. Ramirez, Vice Consul in New York;

United States of America:
C. A. Bates, Electrical Engineer, Bryant Electric Company;
W. F. Durand, Professor of Mechanical Engineering, Stanford University;
A. E. Kennelly, Professor of Electrical Engineering, Harvard University;
F. R. Low, Editor, *Power*;
C. O. Mailloux, Consulting Engineer;
J. Franklin Meyer, Physicist, Bureau of Standards;
A. H. Moore, Electrical Engineer, General Electric Company;
R. W. Owens, Design Engineer, Westinghouse Electric & Mfg. Co.;
F. D. Newbury, Manager, Power Engineering Department, Westinghouse Electric & Mfg. Co.;
D. W. Roper, Supt. of Street Department, Commonwealth Edison Company;
C. E. Skinner, Assistant Director of Engineering, Research Department, Westinghouse Electric & Mfg. Co.;
E. A. Snyder, Chemist, General Electric Company;
N. W. Storer, General Engineer, Westinghouse Electric & Mfg. Co.;

Following the adjournment of the plenary session the delegates left on the official tour, to cover a period of twelve days, April 23 to May 5 inclusive. Transportation for the entire trip was furnished to all accredited foreign representatives and many sight-seeing trips, luncheons and dinners were arranged by local committees in the various cities. The cities visited were: Philadelphia, Washington, Pittsburgh, Chicago, Detroit, Niagara Falls, Ottawa, Montreal, Boston, and Schenectady.

Plenary and Technical Meetings

The technical work of the Commission is placed in the hands of advisory committees, of which there are now ten studying the following subjects:

- Nomenclature
- Rating of electrical machinery
- Symbols
- Prime movers, hydraulic and steam
- Resistance of aluminum
- Lamp caps and holders
- Voltages for distribution systems and test voltages for apparatus
- Traction motors
- Insulating oils
- Rules and regulations for transmission lines

Experience has shown the necessity for making it a rule that no decision of an advisory committee shall be submitted to the Plenary Meeting for ratification until the national committees have had an opportunity of instructing their delegates on the subject. Whilst this leads to an apparent delay, it can be asserted that in the long run it is really the quickest way, as it reduces to a minimum changes in the decisions reached.

At the New York meetings, a number of matters were ready for final decision, as the following reports will show:

Nomenclature. This committee is engaged on one of the most difficult, yet perhaps the most valuable of the tasks undertaken by the Commission. The value to the world of a unified technical language is not easily measured, and the production by the I. E. C. of an electrical vocabulary will provide that unity and stability to the language of the engineer, which is so essential to a clear understanding of the written word among all the nations.

The advisory committee consists of representatives from ten countries, but it has found it necessary to delegate the preliminary work to a subcommittee consisting of: Dr. C. O. Mailloux (U. S. A.), Professor Lombardi (Italy), Mr. Van der Well (Holland), Professor Janet (France), Mr. Wharton (England), Dr. Strecker (representing the Teutonic languages), and Professor Chatelain (representing the Slavonic languages). This subcommittee will submit to the different national committees a list of terms and will ask each of the national committees to study the definitions of these terms in the national vocabularies which have already been submitted, and to inform the subcommittee which definition they consider most suitable for adoption. With these replies before them, the subcommittee will submit to the full committee a recommendation in regard to the first list of definitions for adoption by the I. E. C. The British vocabulary has been accepted as the model for the arrangement and classification of the subject matter.

Note: Five countries have already sent in their national vocabularies in either English or French.

Rating of Electrical Machinery. This committee reached definite decisions in regard to the temperature rises of large machines, including steam turbine-driven alternators and alternators not steam turbine driven if of similar high speed construction. The following table shows the decisions:

TEMPERATURE RISES OF LARGE MACHINES (INCLUDING TURBO-TYPE MACHINES)

TABLE I

LIMITS OF TEMPERATURE RISE OF ROTORS MEASURED BY RESISTANCE METHOD

	Class "A" Insulation	Class "B" Insulation
Rotors of steam driven alternators, and all other alternating current machines of similar high speed construction..............	....	90 deg. cent.
Rotors of salient pole machines above 750 kv-a. and of which the stator cores exceed 50 cm. in 1 length axially.................	60 deg. cent.	80 deg. cent.

TABLE II

LIMITS OF TEMPERATURE RISE OF STATORS MEASURED BY EMBEDDED TEMPERATURE DETECTOR METHOD

	Two, or more, coils per slot		One coil per slot	
	Class A	Class B	Class A	Class B
Steam driven turbine driven alternators and all other alternating current machines of similar high speed construction having an output of 5000 kv-a. or more.........	60	80	Detector, outside coil insulation 55*	70*
			Detector, inside coil insulation 65	85
All salient pole machines having either an output of 5000 kv-a. or more, or core length of one met. or more..........................	60	80	Detector, outside coil insulation 55*	70*
			Detector, inside coil insulation 65	85

*For machine windings up to 7000 volts. For machine windings of more than 7000 volts the limiting temperature rise is reduced below the figures specified in the table one and a half degree centrigrade.

Decisions were reached in regard to the methods to be employed for temperature measurements when made by embedded temperature detectors.

The classification of insulating materials into Classes *O*, *A*, *B* and *C*, was definitely confirmed. The classifications agreed upon are practically identical with those which have prevailed for some time in this country, and therefore are not reproduced here.

It was decided to recommend to the national committees the following high-voltage tests on electrical machines:

HIGH-VOLTAGE TESTS

Rotating machines....	Test voltage (one minute)
10,000 kv-a. and up E up to 2000 volts....	$1000\ v + 2\ E$
E over 2000 volts to 6000 volts..........	$2.5\ E$
E over 6000 volts.....	$3000\ v + 2\ E$

I. E. C. Publication 34, Volume I. This I. E. C. publication contains the rules for machines up to 750 kw. size, and it has been decided to extend the scope of these rules and include the decisions reached in regard to large machines so as to make it applicable to all machines other than those for traction purposes.

Spark Gap Dimensions. The British Committee made a proposal that the I. E. C. should establish an international series of spark gap dimensions, and after some discussion, the American spark gap dimensions, which had come into almost universal use, were recommended for adoption.

Experts' Papers. Following the practise started at the Hague, President Semenza invited papers from different countries on subjects named by him, and the following papers were read:

Subject—In each country, what is the importance of the demand for an overload and what are the main reasons for such a demand?

Mr. F. Dupont, Belgium,
Mr. C. F. Hirshfeld, U. S. A.,
Mr. A. Huber-Ruf and Dr. Behn-Eschenburg, Switzerland,
Mr. C. Rodgers, O. B. E., Great Britain,
Mr. R. Liljeblad, Sweden,
Dr. M. Kloss, Germany.

Subject—The Ambient Temperature as a testing temperature of reference and as a climatic entity.
Mr. Roger T. Smith, Great Britain.

Subject—The true meaning of Ambient Temperature, limits of temperature and temperature rise.
Professor E. Morelli, Italy.

Subject—Is it possible to formulate general laws of equivalence between electrical machines having ratings with different temperature rises?
Mr. A. Huber-Ruf and Dr. Behn-Eschenburg, Switzerland.

Subject—Can the thermal capacity of electric machines be made a simple and practical element of Rating?
Dr. A. E. Kennelly, United States.

A general discussion on these papers took place, and at the conclusion, Professor Feldmann, Chairman of the Rating Committee, in his summary of the discussion made the following observations:

1. That there is no general demand for the inclusion of a sustained overload in the I. E. C. rating.

2. If conditions of service or industry make a second rating desirable, the I. E. C. rating should be stated on the nameplate.

Advisory Committee on Terminal Markings. This committee received a report of the small committee which had met in Paris, and invited the members of this committee, with one or two additions, to continue their study at this meeting. This committee is preparing a statement of the position in regard to terminal markings in the different countries for reference to the national committees.

Marking of Battery Terminals. It was found that with the exception of Czechoslovakia, all countries used red for the positive terminal, and blue for the negative terminal of batteries, and Professor List, representing the Czechoslovakian Committee, stated that he was authorized to say that if a decision was reached to adopt that coloring, his country would alter theirs to conform, although this meant reversing the colors now in use in that country. It was therefore unanimously agreed to recommend the adoption of red for the positive terminal and blue for the negative terminal.

There was some discussion as to whether this decision should not be qualified by recommending that brown be used in cases where red is being used as a danger signal, but it was definitely agreed that no confusion was likely to arise, and this proposal was not accepted.

VOLTAGES AT CONSUMERS' TERMINALS

Direct current	Alternating current — Single phase	Alternating current — 3-Phase: Between phase and neutral
1 x 110	1 x 110	110
2 x 110	2 x 110	127
4 x 110	1 x 220	220
1 x 220		
2 x 220		
1 x 440		
1 x 115	1 x 115	115
2 x 115	2 x 115	133
4 x 115	1 x 230	230
1 x 230		
2 x 230		
1 x 460		

One or other of these two series only being used in any country.

Note—In three-phase systems the resulting pressures between the phases corresponding to the standard pressures between phase and neutral given in the above table (column 3) may be considered as standard.

ALTERNATING CURRENT—3-PHASE

Nominal (Mean Value at consumers' terminals)	Maximum Voltages
1,000	1,100
3,000	3,300
6,000	6,600
10,000	11,000
15,000	16,500
20,000	22,000
30,000	33,000
45,000	50,000
60,000	66,000
80,000	88,000
100,000	110,000
150,000	165,000
200,000	220,000
300,000	330,000

Advisory Committee on Symbols. This committee successfully completed the work of preparing a comprehensive list of graphical symbols for heavy current engineering. The importance of the establishment of what is, in effect, a universal language for electrical diagrams hardly needs emphasis. This committee was, in addition, able to submit for definite adoption a list of graphical symbols for electric traction.

Symbol for Ohm. It was definitely decided to adopt Ω as the symbol for ohm.

Advisory Committee on Prime Movers. More sessions of the Advisory Committee on Prime Movers were held at the New York meeting of the International Electrotechnical Commission than at any of the previous meetings. At these sessions the committee discussed the important elements of test codes for water turbines and steam turbines. The five regular sessions were held on April 14, 15, 16, 19 and 20th and between these sessions two large sub-committees developed detailed reports on each of the test codes.

At the first session President Semenza introduced Dr. William F. Durand of Stanford University, California, and Past President of the American Society of Mechanical Engineers, as the Chairman of the Advisory Committee on Prime Movers for the New York meeting. The roll call of official delegates showed that the following countries had sent representatives: Canada, Czechoslovakia, France, Great Britain, Italy, Norway, Sweden, Switzerland, United States of America. Germany is a member of this Advisory Committee but was unable to send a delegate on this subject to the New York meeting. The United States was represented by Dr. Fred R. Low for Steam Turbines and Mr. H. Birchard Taylor for Water Turbines.

At the opening sessions devoted to Water and Steam Turbines, respectively, the Advisory Committee discussed more or less in detail the various proposals of the several national committees which had been presented at the Hague meeting or had been distributed by mail prior to the New York meeting. Topics of the proposals concerning which differences of opinion developed were referred to sub-committees for further study. The two sub-committees submitted full reports at the Tuesday evening meeting, April 20th, and abstracts of these reports were presented to the Plenary Meeting on the following day.

The report on Water Turbines presents thirteen different porposals which cover important decisions in matters of definition, tolerance or margins in guarantees, speed regulation, pressure variations, methods of test and measurement.

The report on the testing of Steam Turbines covers rating, speed regulation, information to be furnished with an enquiry or

order, interval between installation and test, tolerances or margins in guarantees, weighted average steam consumption and methods of making corrections to test data.

Advisory Committee on Lamp Caps and Lamp Holders. Agreement was reached in regard to the dimensions of Bayonet lamp caps and holders. The differences which have hitherto prevailed between the dimensions used in the two or three countries using this type of holder have been successfully eliminated. Agreement has not yet been reached in regard to the screw cap and holder, there being a difference in the depth of the thread between the continental and American standards, and a compromise, which will not put out of action the very large number of lamp holders in use all over the world, is being sought.

Advisory Committee on Voltages. The Plenary Meeting accepted the recommendation of this Advisory Committee that the following voltages should be used for new systems:

Definition of Nominal Pressure. The nominal high voltage shall be the mean voltage at the consumers' terminals and shall be called nominal I. E. C. Voltage of the network of that pressure range.

The maximum voltage at the generators and secondary terminals of transformers shall be considered to be about 10 per cent higher than the mean voltages at the consumers' terminals.

The maximum and minimum values of the voltages according to paragraph 1, and the variations occurring under working conditions will be considered at a later meeting.

Preferred Nominal High Voltages. The high voltages which are underlined in Tables I and II are recommended as the preferred high voltages.

This committee is now endeavoring to set up a series of voltage ranges for insulators for overhead line construction and switch gear.

Advisory Committee on Traction Motors. This committee recommended to the Plenary Meeting the adoption of a specification for traction motors, subject to the French Committee agreeing to one or two of the points which their delegate was unable to accept without reference back.

The following are the principal points:

Scope: The specification relates to all types of Traction Motors.

Classes of Rating: Two classes of rating are recognized:

(a) The I. E. C. continuous rating

(b) The I. E. C. one-hour rating

Overload Test: Sixty seconds with current equal to twice the one-hour rated current at rated voltage without mechanical injury or flashover or damage to commutation.

TEMPERATURE RISES

Continuous rating	Armature & Field Windings	Class A material	Resistance	85
			Thermometer	65
		Class B material	Resistance	105
			Thermometer	75
	Commutator & Collector	Class A and B	Thermometer	85
One hour rating	Armature & Field Windings	Class A material	Resistance	100
			Thermometer	75
		Class B material	Resistance	120
			Thermometer	97
	Commutator & collector	Class A and B	Thermometer	90

Service Conditions: The rating is based on the assumption that the air temperature will not exceed 25 deg. cent.

Advisory Committee on Insulating Oils. This committee in the course of its discussions made considerable progress and has rcommended to the national committees the following recommendations:

(a) That the viscosity of transformer oil be expressed as kinematic viscosity using as a unit the kinematic centi-poise.

(b) That during the next year the viscosity of transformer oil shall be determined at 20 deg. cent. and 40 deg. cent. to the end that at a future meeting of the Advisory Committee a decision can be reached to adopt a single temperature.

(c) That in order to arrive at a practical short-time acceptance test, the research test has to be established first. After all practical and recognized forms of research test have been considered, then the question of the acceptance test to be adopted could be decided. At present only the research test is to be studied and the National Committees should retain their present acceptance tests.

(d) That in order to obtain data to furnish the basis of discussion at the next meeting of the Commission, the following four characteristic tests on transformer oil shall be made: Swedish, Swiss, German, U. S. A.

These tests to be carried out at the following two temperatures:

(a) At the standard temperature as prescribed by the National rules.

(b) At a temperature of 110 deg. cent.

Advisory Committee on Rules and Regulations for Overhead Transmission Lines. This committee has reviewed the rules and regulations for overhead transmission lines in the different countries and it has expressed the wish that those responsible for overhead line construction in the various countries should get into touch with the I. E. C. through their national committee, so that in future they can formulate their rules on the model already laid down. It has been decided that an attempt shall be made to keep the comparison of the rules of the different countries, which was prepared by the Belgian Committee, up to date and furnish each national committee with a copy of this every year.

The Belgian Committee has been nominated to act as Secretary for this work.

A. I. E. E. Annual Business Meeting New York, May 21, 1926

The annual business meeting of the A. I. E. E. will be held on Friday, May 21, at 8:15 P. M. (daylight saving time) in the Engineering Societies Building, 33 West 39th Street, New York City. At this meeting the reports of the Committee of Tellers on the annual election of Institute officers will be presented, as well as the report of the Board of Directors for the year ending April 30, 1926.

In connection with this meeting an interesting program will be offered by the New York Section. More complete information on this meeting will be mailed to the Section membership in advance of the meeting.

Carnegie Institute Special Summer Session

As a result of the demand that has been developing during the past few years, it is announced that this year courses in electricity are receiving special attention in the plans for the Summer Session at the Carnegie Institute of Technology in Pittsburgh. According to plans, the College of Industries will give six weeks' courses, from June 28 to August 6, in elementary electric wiring, advanced electric wiring, elementary principles of electricity, advanced electricity, and elementary principles of radio communication. It is reported that the radio course has been an outstanding success in the summer school work during the past three years.

In addition the College of Industries will give a course in Engineering Drawing and other arts.

Future Section Meetings

Baltimore

Inductive Interference, by H. S. Phelps. Engineers' Club. May 21, 8:15 P. M.

Cincinnati

Joint Meeting with Cincinnati Engineers' Club. Talk by Dean Schneider, University of Cincinnati. May 20.

Connecticut

Annual Meeting. New Haven. May 19.

St. Louis

Automatic Telephoning in St. Louis. May 19.
Annual Meeting. June 16.

Detroit-Ann Arbor

Standard Distribution Systems, by B. L. Huff, Commonwealth Power Corporation, and

A-C. Low-Voltage Networks, by H. P. Seelye, The Detroit Edison Co. May 18.

World Power Conference

According to announcement recently made by the State Department, the World Power Conference will be held at Basle, Switzerland, August 31st to September 12th, 1926; Mr. O. C. Merrill, Executive Secretary of the Federal Power Commission and member of the American Institute of Electrical Engineers has been appointed by President Coolidge as the United States delegate to this convention, the nomination having been made in response to an invitation received from the Swiss National Committee of the World Power Conference when the first world Power Commission met in London, 1924. This Commission was organized for the purpose of obtaining information and data concerning industrial and economic sources of power, both national and international. The meeting this year will be held simultaneously with the International Exhibition for Inland Navigation and is a special session called to discuss certain economic and financial features in the production of power.

Increase in Salaries of Federal Judges

The new Graham Bill in support of the increase of salaries for Federal Judges has been approved. It is believed that this will have a strong influence for good in maintaining the caliber of the courts, and their proceedings.

Museum of Peaceful Arts

A commission has been appointed to investigate the technique of museum development abroad in conjunction with the establishing here of a Museum of Peaceful Arts. These delegates will report back on their respective commissions; Mr. John W. Lieb has been appointed to report on light, fuel and power; Doctor Samuel W. Stratton, president of the Massachusetts Institute of Technology, on ship models, navigation and aeroplanes; Doctor H. Foster Bain, formerly Director of the United States Bureau of Mines and now Secretary to the American Institute of Mining Engineers, will attend the International Geological Congress to be held in Madrid in May, Doctor Louis Livingston Seaman will study medicine and hygiene and Doctor Ambrose Swasey, manufacturer and inventor, will report upon optics and physics. Elmer Ambrose Sperry, inventor and electrical engineer, sailed for Europe early in April, to study gyro-compass, aeroplane and ship stabilizers, high-power search lights and other devices in line with his special interests. Mr. Calvin W. Rice, Secretary of the American Society of Mechanical Engineers, and honorary secretary of the Museum, also sailed on April 10th. Other interests will be investigated and developed.

AMERICAN ENGINEERING COUNCIL

REPORTS ON COUNCIL WORK

At the recent meeting of the A. E. C. Administrative Board, Louisville, Ky., April 2nd, important matters upon which the Council has been working were reported as having shown encouraging progress. Progress Reports of the Department of Public Works and from the Committee on Street and Highway Safety were received. Of the seven continuing committees established by the Second National Street and Highway Conference, it was determined by the committee in charge that engineering representation should be had on at least five.

John Fritz Medal Presented to Edward Dean Adams

Edward Dean Adams was presented with the John Fritz Gold Medal on March 30 in the Engineering Societies Building, New York. Mr. Adams was chosen the medalist for the year 1926 for great achievement as an "engineer, financier, scientist, whose vision, courage and industry made possible at Niagara Falls the birth of hydroelectric power." The John Fritz Medal is awarded annually by representatives of the A. I. E. E., the A. S. M. E., the A. I. M. E. and the A. S. C. E. for notable scientific or industrial achievements. It was established in 1902 to perpetuate the memory of the achievements of John Fritz in industrial progress.

Dr. F. B. Jewett, Chairman of the Board of Award presided at the presentation and addresses were made by Hon. J. M. Beck, formerly Solicitor-General of the United States and Dr. A. E. Kennelly of Massachusetts Institute of Technology. Major F. J. Miller Chairman of the Board during 1925 presented the medal and Mr. Adams responded with a speech of acceptance.

Hon. J. M. Beck in commenting on the accomplishments of the medalist said in part:

It is a curious fact that our nation, so wonderfully rich in achievement, has been singularly slow and niggardly in the recognition of worth, outside the narrow sphere of political life, and very limited in that respect. This may arise from two divergent theories that have always marked the life of America: the one, the theory of the pioneers, the ideal of inequality, and the other, the political theory of America, the ideal of equality. The two ideals are not consistent, although each has persisted in the minds of America and each has sensibly influenced the other.

As to the theory of inequality, by which I mean the theory that in the inevitable competion of life, "the race is to the swift and the battle to the strong," and that the true glory of man is in superiority rather than in equality—this theory has been the driving force of the American people.

But over and against this dynamic purpose of the American people—each man to do the best for his own life and to rise above his fellows if he can—is the political philosophy that all men are created equal. Nowhere in the Constitution is any power given to the Federal Government to recognize achievement, with one exception, and that a very restricted one, found in our patent system.

With few exceptions, such as the Congressional Medal of Honor for distinguished service in the Army, our Government has from the beginning steadily discountenanced any official recognition of public service.

Because of this lack of fitting recognition of genius and ability by the State, the Engineering Societies are to be the more congratulated for having thus supplied the deficiency in their own field. I wish that every department of activity had a "John Fritz" medal that would mark great achievement in some line of work. There are certainly great advantages in the fact that a medal like the John Fritz Medal should come from those who are experts in the particular field of human activity in which the achievement has been made. And yet I venture to express the hope that some day our nation will create a great national commission which would once a year award a medal to some citizen who, either in that year or in his lifetime, had rendered some exceptional service to the State.

There is one other thought to which I want to give very inadequate expression, and that is the respect in which the award of this medal to Mr. Adams particularly appeals to me. Mr. Adams is of that class of men—a very rare class—who, by example and precept, go far to solve what is the great enigma of our time, the reconciliation of the ever-increasing growth of dynamic power with the growth of the spiritual power in human life. In other words, if there be one enigma which thoughtful men of all nations

are now considering more deeply than at any previous time in history, it is whether the high potential of dynamic power either raises or lowers the high potential of man's spiritual nature. In other words, whether the excessive mechanization of human life is not leading to certain evils that may well give concern to all who try, timidly at best, to scan the future.

It would be easy to demonstrate the enormous part that mechanical invention had played in the progress of mankind. But on the other hand, there are many wise and thoughtful men who perceive that an excessive mechanization of human society is bound to have baleful and portentous effects upon the human spirit. It is the greatest problem with which, in my judgment, humanity has to deal.

If there be any solution of this question, it lies, it seems to me, in a class of men, true leaders in human life, being developed, who are men of telescopic, rather than of microscopic brain.

With the mechanization of human society, human society becomes complex; and as it becomes complex, there is an unavoidable tendency to specialize; and as men become more specialized, of necessity there is a certain disintegration and a lack of solidarity of the social forces of human life. One remedy for that is to develop a class of leadership in the community of men of telescopic brains, who are not merely the devotees of any one branch of human activity, but whose minds are broad and have a natural taste and interest for everything that pertains to mankind.

That is the characteristic of Edward Dean Adams.

It is not only on the personal side of his character that I would prefer to dwell, but it is in respect to his versatility that I think this John Fritz Medal is so well and wisely bestowed. Indeed, all mankind has been his interest. In any department of activity, be it philanthropy, art, literature, music, engineering, industry or finance, wherever he has seen an opportunity for service, he has undertaken to render that service.

I do not know how I can better end these scattering and inadequate observations, or end my individual tribute to Mr. Adams than by quoting the words of no less a man than George Washington, applied to the first electrician of America and the first inventor of his age—Benjamin Franklin.

And so, interpreting the sentiments of all Mr. Adams' friends I venture to say, in the words of Washington: "If to be venerated for benevolence; if to be admired for talents; if to be esteemed for patriotism; if to be beloved for philanthropy can gratify the human mind, you must have the pleasant consolation to know that you have not lived in vain."

Dr. A. E. Kennelly in paying further tribute to Mr. Adams spoke in part as follows:

Looking back from 1926 to the year 1890, it seems now so easy to imagine how a power-transmission plant might then have been brought into existence, in view of the developments which have occurred since that period; but at that date, it was a matter of extraordinary difficulty. Competent scientists and engineers were at variance in their opinions, as to how power might be developed and transmitted from the Falls.

It is therefore all the more wonderful that, in the history we are considering this evening, the initial steps were taken upon a scale that was then gigantic. The Niagara plant is a monument to our medalist, in that the vast scheme he gradually developed, commencing in 1890, has known no retrogression or change of plan, upon any appreciable scale. The great hydro-electric transmission system, as he first visualized it, has come steadily into existence, step by step. It required great foresight, courage, patience and tenacity of purpose, to take the responsibility that rested on his shoulders, as the leader of a band of financiers, organisers and engineers, to initiate that great undertaking.

It may be claimed that Mr. Adams has transported part of the cataract from Niagara to a myriad homes and factories.

He has carried there the power of those falls and the gleam of their light. There is not a fan motor spinning in any of those homes, but follows imitatively and obediently from afar, the whirl of the great Niagara turbine wheels. There is not a light that shines electrically within those homes, but may be regarded as borrowing its gleam from the laughing waters of the intake canals, as they take their plunge over the wheel pits. Even the laughter-loving children who lay their weary little heads upon their pillows at night, take one more glance at the incandescent lamp, just before some loving hand turns it off, to catch, if possible, one more gleam from the cataract, to carry with them into dreamland.

Not only has the power of this nation and of the whole world been advanced in a material sense by this marvelous deed; not only has American life been made richer, more beautiful, more wonderful by this achievement; but we ourselves have received a certain apotheosis by this conquest of the Falls.

So long as human records persist, and so long as the human race is able to read them, Niagara will retain its place as one of the great glories of the world and inseparably associated with it will be the conquest of the Falls, by the harnessing of their waters. When the bridle was thrown over them, the reins lay in Mr. Adams' hands.

We are privileged to see the culmination of that great work recognized by this ceremony here tonight. All honor to the man and to the deed.

In his response in accepting the medal Mr. Adams told something of the history of the Niagara development. Among other things he said:

A consideration of the nebulous state of the art of hydro-electric development and electrical transmission of power at that time is necessary to a proper understanding and appreciation of the work begun at Niagara Falls in 1890-1891. Contemplation of the original project reveals also the remarkable foresight of the founders and of the International Niagara Commission formed for the purpose of reporting on the project. At that time multi-phase work was virtually unknown in this country and the only alternating current apparatus consisted of small single-phase belted machines never run in parallel and seldom driving motors. The size of the hydraulic and electric units adopted at Niagara Falls was far greater than anything ever attempted. The style was absolutely new.

The history of the enterprise is contemporaneous with that of the electrical industry. The Niagara River Hydraulic Tunnel, Power and Sewer Company was organized in 1886 to promote the development of Niagara River under the plans of Thomas Evershed. Its present name, The Niagara Falls Power Company, was adopted in 1889 at which time contracts were made with The Cataract Construction Company for all work contemplated including hydraulic, mechanical and electrical design as well as the management and operation of the completed project.

Although the financial set-up of the original Niagara Falls Power Company and the personnel of its directorate have been greatly overshadowed by the engineering achievement, this part of the company's activities is none the less historic. It marked the liberation of American industry from European financial dominance. Heretofore all projects of any magnitude in the United States were financed in Europe and the hydro-electric development at Niagara Falls was perhaps the first great enterprise in this country built with American capital.

And yet, while The Niagara Falls Power Company sought no funds in Europe, it did seek there engineering aid and advice, for the reputation of the Swiss, Italians and French in hydraulics was well established, and England excelled in mechanics.

It was evident that the services of only the most experienced should be enlisted for guidance in such an enterprise and that commitment to the project should await consultation with those specializing in the general branches of the science involved.

Investigations in Europe led to the formation of a group of international scientists who undertook the joint consideration of engineering projects under the title of The International Commission, with headquarters in London. The records of that Commission form an important chapter in the history of the several sciences and particularly that of electricity inasmuch as the formation of that commission marked probably the first of the notable international conferences of scientists for industrial purposes. Lord Kelvin, then Sir William Thomson, presided as Chairman.

The decisions to abandon the old method of water-power development by a mill over a wheelpit and to adopt a central station for the development of water power and its distribution by compressed air, electricity or water under pressure were announced December 14, 1891. The official decision to adopt the alternating current was announced May 6, 1893, and the first contract for electrical generators was executed in October, 1893, for three alternators of 5000 horse power each.

The decision to adopt electricity, and particularly alternating current electricity, was not accepted without protest.

The controversy between the proponents of direct current and alternating current raged furiously in the early '90s. Thomas A. Edison, the electrical wizard, was the staunch and uncompromising advocate of direct current in the United States, and in Europe, Sir William Thomson, afterwards Lord Kelvin, the most famous physicist of his day, also espoused the cause of direct current. Westinghouse and Stanley in this country, and Ferranti, Brown, Mascart and Turrettini and others in Europe, championed alternating current.

However, it is obvious that the electric light and power industry would scarcely have made the remarkable advances it has were it not for the adoption of the alternating current in the initiation and propagation of which The Niagara Falls Power Company has borne a prominent and historic part.

Thus the influence of Niagara has spread broadcast over the earth, as though it were foredestined to inaugurate new impulses towards the development of world progress through the peaceful arts. Niagara has stimulated and focussed attention on water-power development, on electric transmission and on the utilization of electricity in the electro-chemical, electro-metallurgical and kindred arts. It is symbolic of engineering courage, daring and achievement, and prophetic of the fact that man is continually adapting and applying the natural resources and his genius toward the advancement and glory of civilization.

Prior to the presentation exercises a dinner was given to Mr. Adams in the Engineers' Club at which short addresses were made by W. H. Onken, Jr., editor of the *Electrical World*; L. B. Stillwell, chairman of the Engineering Foundation, and Prof. C. F. Scott of Yale University.

A large number of messages of congratulation were received from well known scientists, engineers, financiers, public officials and others.

Research Graduate Fellowships at University of Wisconsin

COLLEGE OF MECHANICS AND ENGINEERING

For the purpose of promoting engineering research and the development of qualified research men, the University of Wisconsin has established three research fellowships in the College of Engineering. These fellowships are granted under the following conditions:

Each fellow will be appointed for a period of two years, subject to satisfactory service. The salary will be $900.00 for the first year and $1100.00 for the second year. The fellow will be required to devote not less than half his time to assigned research work in the College of Engineering, but will, in any case, be given opportunity to complete his work for the M. S. degree within the two-year period. Candidates must be graduates of engineering colleges of recognized standing, and preferably should have had one or two years' graduate study or teaching or engineering experience. The period of service required will be the usual academic year, including the short vacations. The College of Engineering possesses well-equipped laboratories in which a considerable amount of research work is always under way. Results are published, from time to time, in bulletins of the Engineering Experiment Station. A total of sixty-three bulletins have been published up to the present time.

Applications for these fellowships for the year 1926-27 are now invited. For further information and application blanks, address F. E. Turneaure, Dean, College of Mechanics and Engineering, Madison, Wisconsin.

First Part of New Electrical Safety Code Now Ready

Rules for the installation and maintenance of electrical equipment in generating stations and substations are given in a new publication of the Bureau of Standards of the Commerce Department. These rules cover the general protective features of the station, as well as specific sections dealing with grounding, rotating equipment, storage batteries, transformers, conductors, fuses, switches, switchboards, and lightning arresters.

The first part of the code is known as Handbook 6 of the Bureau of Standards. Copies may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 10 cents each.

Special Exhibit of the American Electric Railway Association

During the period of October 4th to 8th inclusive, the American Electric Railway Association will hold its 45th Annual Convention at Cleveland, Ohio, with a special Manufacturers' Exhibit, to which both floors of the large Cleveland Public Auditorium will be given over. October 6th has been set aside as a day devoted entirely to demonstration of the exhibit and no technical sessions of any kind will divert attention from it on that day,—a day of inspection only.

Muscle Shoals Bids

The Special Joint Congressional Committee appointed to negotiate a lease of the Government Muscle Shoals property has received seven bids for leasing the entire project and two bids for leasing Plant No. 1.

These bids were opened April 10th by Representative James, of Michigan, Acting Chairman of the Committee, and momentary announcement is expected as to recommendations for the acceptable bid.

New York Section Holds Student Convention

On Friday, April 23rd, the New York Section held its first Student Convention. The convention was held in conjunction with a regular monthly Section meeting. All the details of the part taken by the students representing the eight colleges in the New York District were worked entirely by a Student Convention Committee, the New York Section officers and faculty representatives acting merely in an advisory capacity.

The convention proved a great success as instanced by the number and enthusiasm of the students participating and the quality of the student papers and discussion. Friday morning was devoted to inspection trips to the General Electric Lamp Works, the I. R. T. repair shops and the Bell Telephone Laboratories. The afternoon session held in the Engineering Societies Bldg., was opened at 2.30 by Student Chairman, J. C. Arnell, who promptly called upon Past-President Farley Osgood. Mr. Osgood gave an address devoted largely to advice to student prospective engineers, on the type of education likely to produce best results. Mr. Osgood's talk was very enthusiastically received. Eight students then presented papers as follows: "Recent Developments in the Manufacture of Vacuum Tubes," by D. Y. Smith, Cooper Union; "Field Measurements in Radio," by Mr. Remy, Columbia; "Measurements of High-Frequency Oscillations," by Lloyd Goldsmith, Brooklyn Polytechnic; "Engineering Applications of the Gyroscope," by Lincoln Walsh Stevens; "Automatic Telephony," Mr. Schneerveis, City College; "Cooperative Education from the Student's View Point," E. C. Fischer, Newark College of Engineering; "The New Cooperative System at N. Y. U." Theodore Smith, New York University. These papers were actively discussed. A committee appointed by the New York Section then judged the papers and a prize of $25.00 in gold was awarded Mr. Goldsmith, of Brooklyn Polytechnic, for the best presentation.

Following the afternoon session, the students and Section members, about 200 in all, had supper at the Fraternity Club. The New York Section held a regular meeting at 8.15 p.m. in the Auditorium of the Engineering Bldg. Chairman Kidder, presiding, announced the results of the election of Section officers for 1926-27, as follows: Chairman, E. B. Meyer, Public Service Electric Co. of N. J.; Secretary-Treasurer, O. B. Blackwell, A. T & T. Co.; Executive Committee, J. B. Bassett, General Electric Co.; and C. R. Jones, Westinghouse Elec. & Mfg. Co. A paper on "Refrigeration-Theory, History and Recent Developments" was then presented by A. R. Stevenson, Research Engineer, General Electric Co.

Philadelphia's Sesqui-Centennial

Any Institute member who may visit Philadelphia during the Sesqui-Centennial Year, 1926, will be extended the privileges of the Engineers Club of Philadelphia for a period of ten days, provided he brings a letter of introduction from an officer of the Institute.

Another announcement of interest to Institute members in connection with the Sesqui-Centennial is that a number of meetings will be held in Philadelphia during September by the Congress of American Industry.

ENGINEERING FOUNDATION

ARCH DAM INVESTIGATION

The work of the test investigations on the so-called "Stevenson Creek Test Dam," situated on a tributary of the San Joaquin River, 60 miles east of Fresno, Calif., is progressing. Since the December bulletin, the excavation in the granite for the dam foundation has been completed, the remainder of the instruments and accessories for the test obtained, the installation of the

construction plant finished, the test party camp established in camp and methods and programs for the test determined so far as possible in advance of actually putting them into practise. While the concrete is being placed, many instruments will be inbedded and preliminary observations taken. Other tests on concrete materials, concrete instruments and methods have been progressing. As previously stated, the Committee in charge will welcome any information which may be used in the study and preparation of the report, constructive criticism of its program and methods and general discussion of the design of arch or multiple-arch dams. Such correspondence should be addressed to the secretary, F. A. Noetzli, 928 Central Building, Los Angeles, California.

Westinghouse Annual War Memorial Scholarships

The Educational Department of the Westinghouse Electric and Manufacturing Company has just announced the plans for awarding the 1926 War Memorial Scholarships. These awards are made annually, the successful candidate receiving $500 during each year of his collegiate training, or a maximum of $2000.

Applicants eligible to compete for these Scholarships include sons of employees who have been with the Company five years, or more, and employees who have been continuously in the service for at least two years and who shall not, on September 1, have exceeded the age of 23.

Chandler Gold Medal Award

Award of the Chandler Gold Medal was made by Columbia University to Samuel Wilson Parr, professor of applied chemistry, University of Illinois. Professor Parr delivered his lecture at Havemeyer Hall, Columbia University, Friday evening, April 23d. Friends of the late Professor Charles Frederic Chandler, pioneer in the chemistry of this country and founder of the American Chemical Society, presented to the trustees of Columbia in 1910 a sum of money constituting the Charles Frederick Chandler Foundation; it is the income from this fund which is used to provide a lecture by some eminent chemist and the gold medal to be presented to the lecturer in further recognition of his achievements in science.

PERSONAL MENTION

W. J. Swales, after twelve years of service in Latin America and Cuba and of late Superintendent of the Cia Electrica De A. Y. T. de Santiago de Cuba, has resigned his position to return to his home in Canada, where he will enjoy a well earned vacation of three or four months with relatives and friends.

P. M. Rainey, who joined the Western Electric Company immediately after his graduation from college, has been appointed Telephone Sales Manager of the Graybar Electric Company, successor to the Western Electric Supply Department. This new incorporation took place the first of the present year.

Charles Byron Isaacson, formerly of the All Amenia Cables, Inc., is now associated with the Allied Engineering Company, New York City, as director and officer in charge of commercial development.

William A. Moore has accepted a position with the New York Edison Company, as Engineer of Purchases. For the past eight years Mr. Moore was with Hugh L. Thompson, consulting engineer, Waterbury, Conn. He was also chairman of the A. I. E. E. Connecticut section for the year 1924-25.

William B. Herbst, who was for eighteen years affiliated with the Duquesne Light Company, has resigned to become assistant electrical engineer for The Department of City Transit, Philadelphia, Pa.

H. M. Friend has just returned to the Brooklyn Edison Company after a thirteen months' leave of absence spent with Hugh L. Cooper & Company, consulting engineers on the Muscle Shoals Development. Mr. Friend attended to the inspection of all wire, cable and insulators for the Wilson Dam Power House, supervising and testing the installations.

Harrison D. Panton, who, for the past three years has been the principal of Harrison B. Panton & Company, Raleigh, N. C., has joined the organization of Francis R. Weller, consulting engineer, Washington D. C. Mr. Panton's new work will take him to Ocala, Florida, where he will be chief engineer in charge of all Florida-Georgia operations of the Weller organization.

E. O. Shreve, manager of the San Francisco office of the General Electric Company since 1918, has been named manager of the industrial department of the company with headquarters at Schenectady, filling the vacancy caused by the recent death of A. R. Bush.

J. W. Alvord to Receive Washington Award

John Watson Alvord, consulting engineer, has been selected to receive the Washington Award for 1926. The award will be presented at the Annual Meeting of the Western Society of Engineers on June 2.

The award is made annually by a committee of representatives from the Western Society of Engineers and the A. S. C. E., the A I. M. E., the A. S. M. E. and the A. I. E. E. It was established in 1917 "to be presented annually to an engineer whose work in some special instance or whose services in general have been noteworthy for their merit in promoting the public good."

Obituary

James Winthrop Thomas, Fellow of the Institute and brother of Percy H. Thomas, died at his home, Plandome, L. I., April 13, 1926, in the 52nd year of his age.

Born at Boston, November 13, 1874, Mr. Thomas attended Exeter Academy, from which he entered the Massachusetts Institute of Technology, graduating in 1895 with a Mechanical Engineering degree. After serving a short apprenticeship with the Boston and Maine Railway Company in their shops at Cambridge, he went with the Wyoming Shovel Works, Wyoming, Pa., where he became assistant superintendent; thence he went to the Westinghouse Church Kerr & Company, for whom he was in charge of important installations including Westinghouse Lamp Works at Watsesing, N. Y. and Westinghouse stoker works at Attica, Nassau Hotel, Long Beach, L. I., N. Y. He then became engineer of the New England Engineering Company for a short period, leaving them to join the United Gas and Electric Company of Connecticut, where for many years he handled a great variety of work for their various properties.

Mr. Thomas was a member of The American Society of Mechanical Engineers, Fellow of the Institute of Electrical Engineers since 1920, a member of the Technology Club of New York and of the Phi Beta Epsilon Fraternity.

Herbert Wallace Cheney, who, for the past twenty years has been connected with the electrical engineering department of the Allis-Chalmers Manufacturing Company, died at his home in Milwaukee March 22d, 1926, after an illness of two months.

Mr. Cheney was born at Coldwater Lake, Michigan, February 7, 1872. Here he received his primary education through the small country school later attending the Valpariso University. After graduating from the university, he returned to Coldwater to teach and later entered the University of Michigan for the purpose of completing his engineering studies.

Following his university course, he was, for a short time, with Frank M. Dunlap, Consulting Engineer, Detroit, Michigan, spending also a few months with Charles A. Strelinger Co., Detroit, Michigan, as designer of machine tools. In January

1893 he entered the employ of the Leland & Falconer Manufacturing Company of Detroit who later became the Cadillac Motor Car Company. Six years later, Mr. Cheney went with the Westinghouse Electric & Mfg. Co., In 1904, when the Allis-Chalmers Company took over the Bullock Electric Manufacturing Company, Mr. Cheney joined the engineering department of the Bullock Plant, Cincinnati, as engineer in the design of detail electrical apparatus. In 1908 the engineering work was consolidated at the West Allis Works and Mr. Cheney moved to Milwaukee his work being particularly in connection with detail apparatus, airbrake equipment, small motor-driven air compressors, motor starters, etc.; he was also in executive charge of the experimental department for them. When Allis-Chalmers were making arrangement with A. Reyrolle & Company for the building of armorclad switchgear in this country, Mr. Cheney was sent to England with other engineers, to investigate the design of this new switchgear. To this work he was devoting his attention at the time of his death. Mr. Cheney was a Fellow of the Institute; he also served the Milwaukee Section as its chairman and on its program and membership committees. He was a member of the American Society of Mechanical Engineers, the Milwaukee Engineers' Society with which organization, during the past year, he was chairman of a committee on Education and Graduate Training. He was of a nature which endeared him to a large circle of friends while his earnest interest in all undertakings caused him to be held in high esteem by his associates.

William F. Meschenmoser, Vice-President of the Russell & Stott Company, New York City, died on March 16th, 1926. Mr. Meschenmoser was born in Brooklyn, December 4th, 1876. His fundamental education in mathematics, physics, chemistry, electrical and mechanical engineering was practically self acquired. He studied train control systems for two years, designing and drafting, one year; design and shop, electrical and mechanical for four years; was machine shop superintendent for five years and machinist and apprentice for four years. From 1894 to 1899, he was superintendent of design and building small special machinery for the Excelsior Co. He then identified himself with the F. W. Mills Company as superintendent of automatic electrical and mechanical machinery. From 1903 to 1904 he was working for himself at general electrical and mechanical machine design and construction supervision, but in 1904 joined the Kinsman Company, with whom he was engineer with general supervision of drawing room and field. For a number of years, Mr. Meschenmoser was active on the Committee of Application to Marine Works, beside rendering valuable service to the Institute and the profession in many other ways.

Charles G. M. Thomas, Associate of the Institute and Vice-President of the Consolidated Gas Company of New York died at his home, Flushing, L. I., March 23, 1926. Mr. Thomas was born July 2, 1866, in New York City and was educated in the city schools and the College of the City of New York. In 1888 he joined the Standard Gas Light Company of the City of New York and remained with them until 1901 in varying capacities, Cashier until 1893 and manager until 1901. He was then made vice-president and general manager of the Newtown & Flushing Gas Company, the New York and Queens Gas Company, the Williamsport (Pa.) Gas Company and the Dallas, (Texas) Gas Company, operating from New York City. In this office he remained until 1907, when he concentrated as vice-president and general manager of the New York & Queens Electric Light and Power Company, of which he was also chairman of the Board of Directors at the time of his death. Mr. Thomas' popularity and success in his undertaking may be emphasized, perhaps, by the fact that over 500 people were present at the services held for him at the Dutch Reform Church, Flushing.

Gordon Oke Philp, who, since 1919, has been superintendent of the Hydro-Electric Power Commission of Ontario, died at Niagara Falls, of blood poisoning contracted several months ago. Mr. Philp his associates felt, was destined for a most brilliant future and the Commission acknowledges the loss of a most capable executive. Born at Port Hope, August 17, 1892, he was educated through the public and high schools there. He decided to become an engineer and as soon as possible entered the University of Toronto, graduating from there with his degree of Bachelor of Applied Science in 1914. Vacation periods were spent with the Midland Construction Company in Central Ontario. After graduation he entered the engineering department of the Electric Power Company and when this company was taken over by the Ontario Government in 1916, he joined the operating staff of the Hydro-Electric Power Company. When the Commission acquired control of the Ontario Power Company, Mr. Philp was chosen as the man to assume the position of general superintendent, work required considerable skill and tact. During the last few years, added responsibility has been given him until, at the time of his death, he was satisfactorily holding the position of general superintendent of all operations and maintenance of the Commission's three properties; Queenston Development Company, the Ontario Power Company and the Toronto Power Company. Mr. Gaby, chief engineer of the Hydro-Electric Power Company, pays Mr. Philp the following tribute: "He has achieved success—who looked for the best there was in others and gave the best he had. Whose life was an inspiration and whose memory is a benediction." Mr. Philp joined the Institute in 1919 as an associate but advance to the grade of Member in 1925.

Willard G. Carlton, Superintendent of Power of the New York Central Lines and Fellow of the Institute, died at his home in Yonkers, New York, April 15th, of pneumonia.

Mr. Carlton was born in Warren, Illinois, February 20th, 1869. He was educated in the grammar and high schools of that town prior to his attending Cornell University, from which he graduated in the class of 1892. For one year immediately after his graduation, he was with the General Electric Company at Lynn, Massachusetts, taking their students' course, which he completed in 1893 and joined the Chicago Edison Company, with whom he remained in varying capacities until 1905. He left them to become Superintendent of Power for the Electric Division of the New York Central and Hudson River Railroad, in charge of distribution of power for the operation of electric trains in and near New York City. Mr. Carlton has been described as "an engineer of unusual originality, resourcefulness and force, with a prominent part to play in shaping the development of engineering." As chief operating engineer for the Chicago Edison and Commonwealth Electric Company, he had charge of all underground and overhead distribution systems and substations as well as all direction of extensions of distribution systems for the company. There is little doubt that Mr. Carlton leaves behind him much of future achievement in the profession as well as a host of friends. He served the Institute as a member of the Board of Directors 1908-11 and as Vice-President during the years 1911-13, beside being extremely active in its Committee work. He was a member of the Engineers Club, the New York Engineering Society, The American Society of Mechanical Engineers, the National District Heating Association, the Cornell Club of New York and the New York Railroad Club, all of whom were cognizant of the profitable and pleasant relationship.

Chester W. Lyman, director and vice-president of the International Paper Company until his resignation about a year ago, died at the Massachusetts General Hospital, April 15th. Mr. Lyman was born in New Haven 64 years ago, the son of Chester Smith Lyman, for many years professor in the Sheffield Scientific School, Yale University. Mr. Lyman attended the Hopkins Grammar School of New Haven and recently helped to raise funds for its reorganization and development. He graduated from Yale in 1882, and after a period of service with the United States Coast Survey, in 1885 identified himself with H. Parsons

& Company, starting his career as a paper manufacturer. In 1890, he joined the Herkimer Paper Company, Herkimer, N. Y., becoming its manager and director. Upon the absorption of this company by the International Paper Company, he continued his interest with them as assistant to the president until he was made vice-president in 1916. In 1895 one year after joining the Institute he was awarded the degree of M. A. for special studies in electrical engineering.

Mr. Lyman has contributed many articles to the trade journals and was an active member of the American Paper and Pulp Association. He also belonged to the American Forestry Association Sons of the American Revolution; and the University, Yale, Piping Rock and Midday Clubs.

Louis Anthyme Herdt, Macdonald Professor of Electrical Engineering, McGill University and vice-president of the Montreal Tramways Commission, died suddenly at his office, McGill Engineering Building, April 11, 1926.

Born at Trouville, France, June 14, 1872, Professor Herdt, while still quite young, came to Canada with his family; his early education was in the Montreal High School, he thereafter entering McGill University to graduate with honors from the Mechanical Engineering course in 1892. During his three years' study at McGill, five months out of each year he was working as assistant engineer for the Laurie Engine Company of Montreal. In 1893, he took a course in electrical engineering at the Institut Electrotechnique Montefiori, Liege, Belgium, graduating with a diploma of electrical engineering. From May 1894 to September 1895, Professor Herdt was assistant electrical engineer to the Thomson Houston International Company, Paris, whence he returned to McGill University, as demonstrator of electrical engineering, becoming consecutively lecturer, assistant professor, associate professor, and, ultimately, head of the department. Doctor Herdt was president of the Electrical Service Commission of Montreal, a member of the Engineering Institute of Canada, and Fellow of the American Institute of Electrical Engineers. In 1907 he was appointed delegate to the International Electrotechnical Commission, meeting then in London, England, and it was with deep sympathy and regret that the Commission, meeting in this country for the first time this year, heard of his untimely death. He was appointed Officer d'Academie de France in 1905 and Chevalier de Legion d'Honeur in 1923. Doctor Herdt was the author of several technical papers and contributed materially to the work of profession, both through the technical press and the engineering bodies with which he was identified. Beside his membership in the Engineering Institute of Canada, Doctor Herdt belonged to the Montreal Engineering Club.

Engineering Societies Library

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 5 p. m.

BOOK NOTICES (MARCH 1-31, 1926)

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statement made; these are taken from the preface or the text of the book.

All books listed may be consulted in the Engineering Societies Library.

DIE ANWENDBARKEIT DER GEOPHYSIKALISCHEN LAGERSTATTENUNTERSUCHUNGSVERFAHREN, INSBESONDERE DER ELEKTRISCHEN UND MAGNETISCHEN METHODEN.

By Rudolf Krahmann. Halle (Saale), Wilhelm Knapp, 1926. 40 pp., 10 x 7 in., paper. 2,50 gm.

With the object of supplying the mining interests with a comprehensive, understandable presentation of the fundamental principles of the practical use of geophysics in the study of ore deposits, the author has prepared this brief survey of the practical geophysical methods for the exploration of ore deposits. The various methods, using the measurement of electromagnetic conductivity, specific potential, magnetic intensity, gravity, elastic waves, earth temperatures and radioactivity are described, and their possibilities pointed out. A bibliography is included.

BEITRAG ZU DEN GRUNDLAGEN DER SCHNELLAUFENDEN HALBDIESELMOTOREN.

By Karl Büchner. Halle (Saale), Wilhelm Knapp, 1926. 48 pp., illus., 11 x 7 in., paper. 3,50 mk.

A lecture upon certain directions in which there is a tendency toward technical advance in the utilization of heavy oil. The author calls attention to the possibilities of solid-injection for high-speed automobile engines as well as for stationary and marine Diesel engines. He next speaks of recent satisfactory adaptations of hot-bulb engines to automobiles, in controversion of the usual idea that this type is an antiquated step in the evolution of the engine. Finally, he suggests the desirability of more thorough investigation of the reactions underlying the formation of mixtures which ignite easily and burn rapidly. He devotes special attention to this third point.

DIE BEWEGLICHKEIT BINDIGER UND NICHT BINDIGER MATERIALIEN.

By V. Pollack. Halle (Saale), Wilhelm Knapp, 1925. 139 pp., 10 x 7 in., paper. 9,80 g. m.

Professor Pollack's monograph which brings together our knowledge of the mobility of cohesive and non-cohesive materials, treats a matter of great importance to geologists and civil engineers. The behavior of loam, clay, colloidal mud, sand, etc., under varying conditions of pressure and moisture is described and information given on their plasticity, cohesion, consistency and similar properties.

DYNAMICAL THEORY OF SOUND.

By Horace Lamb. 2nd edition. Lond., Edward Arnold & Co., 1925. 307 pp., 9 x 6 in., cloth. $6.00. (Gift through Longmans, Green & Co.)

Although a treatise on this subject is of necessity to a great extent mathematical, the author has tried to restrict himself to the simplest and most direct methods and processes possible, in view of the questions treated. In this sense the book is elementary and will, the author hopes, serve as a stepping stone to the writings of Helmholtz and Rayleigh.

This edition has been corrected and revised.

ECONOMICS OF THE RADIO INDUSTRY.

By Hiram L. Jome. Chicago, A. W. Shaw Co., 1925. 332 pp., diagrs., tables, 8 x 6 in., fabrikoid. $5.00.

A discussion of the economic and legal problems caused by the development of wireless communication. Taking the point of view that the function of radio is to render a more or less distinctive service of communication, the author analyzes its service problems as they affect society. He first discusses the development and extent of the industry, then most effective ways for making this service available to the people. The problems confronting the organizations rendering the service are then considered, while the final section of the book discusses the future of radio service and its relation to other social agencies and means of communication.

DIE ELEKTRISCHE TELEGRAPHIE MIT DRAHTLEITUNG, vol 1; Die Telegraphie mit Morsezeichen.

By J. Herrmann. Berlin u. Leipzig, Walter de Gruyter & Co., 1926. 134 pp., illus., 6 x 4 in., cloth. 1,50 mk.

The first volume of a brief practical textbook on telegraphy. This book is confined to telegraphy with Morse signals, the subject of printing telegraphs being left for a second volume.

The book opens with a brief review of the elements. The various circuits are then discussed, after which the author proceeds to cable telegraphy and high-speed systems. An excellent brief survey of the subject.

ENGINES OF HIGH OUTPUT; Thermodynamic Considerations.

By Harry R. Ricardo. Lond., Macdonald & Evans, 1926. (Reconstructive technical series.) 110 pp., graphs, tables, 9 x 6 in., cloth. 7 6.

Some years ago Mr. Ricardo published a series of articles giving a brief general analysis of the possibilities and limitations of high-speed gasoline engines. The present book is the first volume of a revision and amplification of that analysis. It deals particularly with the thermodynamic aspects of the problem. The author inquires into the factors that determine the efficiency of gasoline engines and discusses their application to practical design.

ENGLISH BRASS AND COPPER INDUSTRIES TO 1800.

By Henry Hamilton. N. Y., Longmans, Green & Co., 1926. 388 pp., illus., 9 x 6 in., cloth. $6.00.

Dr. Hamilton traces the development of these industries from their beginnings in the sixteenth century down to the year 1800, when they were firmly established in Birmingham, the city in which they are concentrated today. He is particularly interested in industrial organization, hence, it is the industrial and commercial organization of these industries which he studies rather than the evolution of manufacturing processes. The result is an interesting work which throws new light on industrial development during its period, of interest to students of economics, as well as students of the particular industries under discussion.

DIE ENTWICKLUNG DER DIESELMASCHINE.

By R. Schöttler. Halle (Saale), Wilhelm Knapp, 1925. 50 pp., illus., 11 x 8 in., paper. 3-mk.

Professor Schöttler's monograph gives a concise account of the evolution of the Diesel engine from its beginnings in 1893 to the present time. The development of modern types and of the various details of present designs is covered thoroughly, although briefly, and there are numerous bibliographic footnotes.

DIE FEILE.

By Otto Dick. Berlin, Julius Springer, 1925. 251 pp., illus., 11 x 8 in., boards. 18.-mk.

A handsomely printed, profusely illustrated history of the file, by the engineer of one of the largest German file factories. The book is divided into three parts. Part one, on the history of the file, traces this tool chronologically from the Stone Age to modern times. The second part describes the development of file and rasp cutting machines from the earliest—invented by Leonardo da Vinci in 1503—to the forms in use today. Part three describes the making of files and shows the evolution of the methods. The work is an unusually well planned and executed history of a tool, a model technical history.

GESCHICHTE DER EISENDRAHTINDUSTRIE.

By O. H. Döhner. Berlin, Julius Springer, 1925. 106 pp., illus., 11 x 8 in., cloth. 12-gm.

The author of this handsomely printed little book is a wire manufacturer in Westphalia, the "cradle," as he says, of the wire industry. He traces the manufacture of wire from the earliest times to the beginning of the present century, describing the successive steps by which the industry has advanced to the present stage. Although brief, the book is a careful, critical history, based on long study. The illustrations are carefully chosen from old sources.

DIE GRUNDLAGEN DER HOCHFREQUENZTECHNIK.

By Franz Ollendorff. Berlin, Julius Springer, 1926. 639 pp., diagrs., 9 x 6 in., cloth. 36-r.m.

This textbook is the result of an investigation carried on by the author for the purpose of improving the course of instruction in high-frequency engineering at the Danzig Technical High School. The aim has been not to provide the student with a collection of rules but to give him a thorough grounding in fundamentals, equip him for the independent solution of problems that arise in practice, and especially to teach him to understand scientific literature. Little attention is therefore given to specific machines and commercial varieties of equipment, but rather to topics which are of fundamental physical importance, as, for example, the theory of electro-magnetic radiation.

HANDBOOK OF SAFETY AND ACCIDENT PREVENTION.

By Fred G. Lange. N. Y., Engineering Magazine Co., 1926. 512 pp., illus., graphs, 9 x 6 in., fabrikoid. $5.00.

This handbook aims to bring together the information essential to a proper understanding of the Safety First movement. It gives a general view of the entire field of safety work, describes definite methods of procedure in installing programs for accident prevention, describes many successful methods and provides references to the literature.

INTRODUCTORY ELECTRODYNAMICS FOR ENGINEERS.

By Edward Bennett and Harold Marion Crothers. N. Y., McGraw-Hill Book Co., 1926. 665 pp., illus., diagrs., tables, 8 x 6 in., cloth. $4.50.

In an article published during 1923 in the JOURNAL of the American Institute of Electrical Engineers, Professor Bennett argued the need for separate instruction for engineering students of superior aptitude and those of moderate aptitude; and the provision of introductory textbooks giving a profoundly technical treatment of their subject for the first group and books giving a moderately technical treatment for the second. This text represents the notion that the authors have of the type of introduction to the electrical theory and the electrical principles that are fundamental to design, development, research and technical supervision in the electrical field which students of superior aptitude should receive.

The text is based on the instruction given for seven years at the University of Wisconsin. It aims to facilitate the acquirement of a profound understanding of the subject and is in the form of a connected development in which the observations, definitions, units and laws are taken up in the sequence in which the units of the electrostatic system are defined, each in terms of those preceding it.

RAILWAY TRACK AND MAINTENANCE . . . 4th edition of "Railway Track and Track Work."

By E. E. Russell Tratman. N. Y., McGraw-Hill Book Co., 1926. 490 pp., illus., tables, 9 x 6 in., cloth. $5.00.

A technical account of track construction and maintenance of way, intended for railroad engineers and officials, and for students. It gives the general principles and purposes that underly the design and maintenance of tracks and the systems applicable anywhere in practice. It also gives many details about the equipment, material, appliances and methods used by individual railroads in different parts of the country, under various conditions of traffic and climate. Bridge, signal, telegraph and emergency work are included. This edition has been entirely rewritten.

RECENT ADVANCES IN PHYSICAL AND INORGANIC CHEMISTRY.

By Alfred W. Stewart. 5th edition. N. Y., Longmans, Green & Co., 1926. 312 pp., illus., diagrs., plates, tables, 9 x 6 in., cloth. $6.50.

Contents: The older and the newer chemistry.—X-Ray spectra and automic numbers.—Elements of the rare earths.—Hafnium.—Phenomena of radioactivity.—Disintegration theory and the radioactive series.—Radon, thoron and actinon.—The isotopes.—The isobares.—Analysis of positive rays.—Results obtained with the mass spectograph.—The segregation of isotopes.—Atomic nucleus and its artificial disruption.—Outer sphere of the atom.—Active hydrogen.—Active nitrogen.—Some new hydrides.—Hydrides and the periodic system.—Some effects of intense drying.—Tesla-luminescence spectra.—Conclusion.—Indexes.

The advance in our knowledge in recent years has compelled Dr. Stewart to recast this book so completely that it is practically a new work. New chapters have been written and old text eliminated until but five chapters of the 1920 edition remain.

The new work gives brief, yet comprehensive accounts of recent additions to our knowledge, with numerous references to their literature.

TRAGBARE AKKUMULATOREN.

By Richard Albrecht. Berlin u. Leipzig, Walter de Gruyter & Co., 1926. 135 pp., illus., diagrs., tables, 6 x 4 in., cloth. 1,50 mk.

This book is devoted to portable forms of storage batteries and is confined to the three types—lead, nickel-iron and nickel-cadmium—which have been used commercially.

The author first describes the construction, mode of action and handling of the lead accumulator. This is followed by descriptions of the alkaline accumulators, especially the Edison battery, and a comparison of the two classes. The principal uses of storage batteries, for radio communication, ignition portable lamps and as substitutes for primary batteries are then treated. The book closes with a chapter on methods of charging.

TRAGEDY OF WASTE.

By Stuart Chase. N. Y., Macmillan Co., 1926. 296 pp., 8 x 5 in., cloth. $2.50.

This book is intended to call attention to the waste in industry occasioned by useless and vicious goods and services, by idleness, by unscientific methods of production and distribution and by the waste of natural resources. The author attempts to set forth with some detail the loss through each of these four channels and to estimate the man-power lost through the first three and the waste through the fourth. No solution is suggested, but the book has interest as a vivid, thought-provoking presentation of industrial abuses.

TURBO BLOWERS AND COMPRESSORS.

By W. J. Kearton. Lond. & N. Y., Isaac Pitman & Sons, 1926. 333 pp., illus., diagrs., tables, 9 x 6 in., cloth. $6.00.

Although the turbo blower and turbo compressor have become important in many industrial processes, there have been few serious publications about them in the English language and until now, no book concerning them. In the present work, offered to meet the want, the author has attempted a general treatment which may be useful to students, designers and operating engineers.

A short introduction deals with the principle of the centrifugal compressor and compares reciprocating and rotary compressors. The theory of air compression and the changes of state peculiar to centrifugal compressors are then treated. A theory of the turbo-compressor is then presented, followed by a discussion of the various losses and their influence. Regulating devices are described. Under design, special attention is given to the strength of impellers and the critical speeds of shafts. Methods of testing and some results of tests are given.

UBERSTROME IN HOCHSPANNUNGSANLAGEN.

By J. Biermanns. Berlin, Julius Springer, 1926. 452 pp., illus., diagrs., 9 x 6 in., cloth. 30.-mk.

A rewritten, enlarged edition of "Magnetische Ausgleichsvorgaenge in elektrischen Maschinen." The author discusses transient phenomena in various alternating current systems. Short-circuit processes and their peculiarities are treated in detail as are protective devices. The author is chief engineer of the A E G transformer and high-tension material works and has kept especially in mind the needs of the practising engineer.

VECTORIAL MECHANICS.

By L. Silberstein. 2nd edition. Lond. & N. Y., Macmillan & Co., 1926. 205 pp., 9 x 6 in., cloth. $4.00.

"The main object of this book is to present the chief principles and theorems of theoretical mechanics in the language of vectors and thereby to contribute to the diffusion of the use of vectors," says the author. The book is so arranged that it gives an almost systematic exposition of the chief principles of mechanics which may be used by those acquainted with little more than Alembert's Principle, while to readers thoroughly informed on the subject in its Cartesian form it presents a translation of their knowledge into the shorter vectorial language.

The new edition differs from the first only by the inclusion of some miscellaneous notes.

VIBRATION IN ENGINEERING.

By Julius Frith and Frederick Buckingham. Lond., Macdonald & Evans, 1924. (Reconstructive technical series). 123 pp., diagrs., 9 x 6 in., cloth. 7/6.

The matter of vibration in machinery is frequently of vital importance to makers and users, yet when information is wanted on the subject, it is found that the literature is scattered and difficult to collect. For that reason this book will be of value.

The authors have endeavored to bring together and coordinate the various problems in sound, the strength of materials, mechanics and harmonic motion which enter into the question, and to present the subject of engineering vibration as a whole. They present the subject first from the physical, then from the mathematical point of view, thus making provision for two types of minds.

Addresses Wanted

A list of names of members whose mail has been returned by the postal authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th St., New York, N. Y.

All members are urged to notify the Institute Headquarters promptly of any change in mailing or business address, thus relieving the member of needless annoyance and also assuring the prompt delivery of Institute mail, the accuracy of our mailing records, and the elimination of unnecessary expense for postage and clerical work.

1.—William E. Ames, Detroit Edison Co., Detroit, Mich.
2.—H. R. Bailey, Room 923, Electric Bldg., Portland, Ore.
3.—J. Roy Barclay, 3424 Harrison, Kansas City, Mo.
4.—I. Bergenstrahle, 425 West 114th St., New York, N. Y.
5.—Hubert L. Clary, 782 West 24th St., Milwaukee, Wis.
6.—J. F. Clinton, 3682 Broadway, New York, N. Y.
7.—J. E. Contesti, 350 W. 58th St., New York, N. Y.
8.—Hugh Denehy, c/o The Secretary, The Inst. of Elec. Engrs., Savoy Pl. Victoria Embankment, London, W. C. 2, England.
9.—Ralph Elsman, 120 Broadway, New York, N. Y.
10.—Charles A. Foust, 10505-93rd St., Woodhaven, N. Y.
11.—George Frasher, 1209 So. 4th Ave., Louisville, Ky.
12.—S. Alden Griffin, 19 Elliott St., Springfield, Mass.
13.—Harold G. Haines, 7416 Sylvester, Detroit, Mich.
14.—William A. Hincy, Colonial Apts., Media, Pa.
15.—Elmer D. Johnson, 1481 Harvard St., Washington, D. C.
16.—D. Brainerd Jones, 131 25th St., Jackson Heights, N. Y.
17.—John E. Lewis, 376 Meyran Ave., Oakland Sta., Pittsburgh, Pa.
18.—F. A. Lindlof, 610 So. Spring St., Los Angeles, Calif.
19.—Charles Wm. Lucek, 1454 First Ave., New York, N. Y.
20.—Charles W. Magee, c/o Pelser, 210 West 102nd St., New York, N. Y.
21.—Shu-Sing Man, Apt. 53, 541 West 124th St., New York, N. Y.
22.—J. A. McDermott, Y. M. C. A., Lima, Ohio.
23.—Irving Menschik, c/o Dublier Cond. & Radio Corp., 48 W. 4th St., New York, N. Y.
24.—Erwin H. Mitchell, c/o Schmeltz, 481 6th St., Brooklyn, N. Y.
25.—Raymond W. Noddins, 230 East Ohio St., Chicago, Ill.
26.—Frank O. Nottingham, Jr., 417 Rugby Rd., Schenectady, N. Y.
27.—G. C. Poulson, 500 Danforth St., Syracuse, N. Y.
28.—Robert H. Russell, 1128 Warren West, Detroit, Mich.
29.—Lieut. A. G. Scott, 68 West 107th St., New York, N. Y.
30.—Kermit G. Seaman, P. O. Box No. 68, Boulder, Colo.
31.—A. B. Smedley, c/o Cooper Hewitt Elec. Co., 1406 First Natl. Bank, Cincinnati, Ohio.
32.—C. D. Smith, 857 St. Charles St., New Orleans, La.
33.—Will M. Strickler, 301 Detroit Life Bldg., Detroit, Mich.
34.—L. H. Thullen, 280 Madison Ave., New York, N. Y.
35.—O. G. Utt, 4738 Kansas City, Mo.
36.—Leo A. Van Etsen, 1100 Park Ave., New York, N. Y.
37.—John D. Walker, 2686 Woodstock Ave., Swissvale, Pa.
38.—A. R. Williamson, 561 Delaware Ave., Norwood, Pa.
39.—C. A. Winder, Southern Equipment Co., San Antonio, Tex.
40.—M. L. Younger, 1814 Diamond St., Philadelphia, Pa.

Past Section and Branch Meetings

SECTION MEETINGS

Boston

Acoustical Engineering, by J. B. Taylor, General Electric Co. Illustrated. March 16. Attendance 80.

Cleveland

Inspection trip to Nela Park Development Laboratories, during which H. D. Blake gave a talk on "New Developments in Incandescent Lamps." After dinner an address was also made by R. W. Shenton on "The Search for the Obvious." Joint meeting with Akron Section. February 18. Attendance 250.

Connecticut

The New England Power Pool, by Samuel Ferguson, Hartford Electric Light Co. March 9. Attendance 110.

The Addition and Subtraction of Colors in Lighting Applications, by A. C. Dick, Westinghouse Lamp Co. March 19. Attendance 50.

Denver

The High Lights of the Gas Industry, by C. A. Harrison, Public Service Co. of Colorado. Luncheon Meeting. January 26. Attendance 60.

The Application of Electricity and Magnetism in Chemistry and Metallurgy, by Dr. M. F. Coolbaugh, Colorado School of Mines. March 19. Attendance 27.

Structural Thermo Insulation, by W. A. Grossman, Intermountain Insulex Co. Luncheon Meeting. March 30. Attendance 75.

Science and the Industries, by Dr. M. I. Pupin, National President, A. I. E. E. March 30. Attendance 800.

Erie

Industrial Electric Heating, by C. P. Yoder, Erie County Electric Co. Illustrated with slides. February 16. Attendance 75.

Mercury-Arc Rectifiers, by D. C. Prince, General Electric Co. Illustrated with slides. March 16. Attendance 65.

Fort Wayne

The Gyroscope, Gyrocompass and Gyropilot, by O. B. Whitaker, Sperry Gyroscope Co. March 18. Attendance 130.

Indianapolis-Lafayette

The Gyroscope, Gyro-Compass and Gyro-Pilot, by O. B. Whitaker, Sperry Gyroscope Co. March 19. Attendance 52.

Communication by Electrical Undulations, by J. Lloyd Wayne, III, Indiana Bell Telephone Co. April 12. Attendance 18.

Lehigh Valley

Power-Factor Correction, by L. W. W. Morrow, *Electrical World*, and *What Diversity Factor and Load Factor Mean to a Community*, by N. E. Funk, Philadelphia Electric Co. March 12. Attendance 102.

Automatic Control of Centrifugal Pumps, by Otto Haentjens, Barrett-Haentjens Co., and

Wallenpaupack Hydro-Electric Development of the Pennsylvania Power and Light Co., by Wm. E. Lloyd, Jr. A dinner preceded the meeting. March 26. Attendance 202.

Los Angeles

General Transportation Situation in Los Angeles, by D. W. Pontius, Pacific Electric Railway Co.;

Industrial Heating, by Max Lee, Westinghouse Elec. & Mfg. Co., and C. J. Cipperly, General Electric Co.; and

Principles of Domestic Electric Refrigeration, by G. H. Hopkins. April 6. Attendance 96.

Lynn

Signal Control for Steam Railroads, by W. H. Reichard. General Railway Signal Co. March 18. Attendance 65.

Madison

The Self-Starting Synchronous Motor, by S. H. Mortensen, Allis-Chalmers Mfg. Co. Joint meeting with University of Wisconsin Branch. March 23. Attendance 50.

Minnesota

Automatic Starters for Synchronous Motors, by G. J. Shavor, Electric Machinery Mfg. Co., and

Synchronous-Motor Applications, by F. H. Milliken, Electric Machinery Mfg. Co. March 29. Attendance 90.

Niagara Frontier

The Quest of the Unknown, by H. B. Smith, Worcester Polytechnic Institute. A dinner preceded the meeting. March 17. Attendance 48.

Oklahoma

Electrical Engineering and State of Oklahoma, by F. G. Tappan, University of Oklahoma;

Oil-Field Electrification, by D. L. Johnson, Westinghouse Elec. & Mfg. Co.; and

Educational Problems, by J. H. Felgar, University of Oklahoma. March 9. Attendance 28.

Philadelphia

Institute Activities, by F. L. Hutchinson, National Secretary, A. I. E. E., and

College, Then What? by Farley Osgood, Consulting Engineer. March 8. Attendance 180.

Pittsburgh

Surge Investigations with the Klydonograph, by J. H. Cox, Westinghouse Electric & Mfg. Co. March 9. Attendance 157.

Oil-Circuit-Breaker Situation from Operator's Viewpoint, by E. C. Stone, Duquesne Light Co., and

High-Power Laboratory and Plans for Test Demonstration, by W. R. Woodward, Westinghouse Electric & Mfg. Co. Dinner preceded the meeting. April 13. Attendance 435.

Pittsfield

Uses of Vacuum Tubes for Purposes Other than Radio, by W. C. White, General Electric Co. March 9. Attendance 55.

The Automobile of Today and Tomorrow, by Herbert Chase, Erickson Co. March 16. Attendance 200.

Portland

Factors Affecting Radio Reception, by C. H. Watson;

The Barrage System of Reception, by A. G. Simson, and

Radio Interference, by Ellis Van Atta, Pacific Power and Light Co. March 17. Attendance 86.

Rochester

Modern Views of Electricity and Matter, by H. C. Reutchler, Westinghouse Electric & Mfg. Co. February 5. Attendance 125.

Railway Electrification—Domestic and Foreign, by H. K. Smith, Westinghouse Electric & Mfg. Co. March 5. Attendance 60.

In the Land of Buddha, by H. B. Smith, Worcester Polytechnic Institute. March 16. Attendance 120.

San Francisco

The Hydro-Electric Power Development at Hetch Hetchy, by N. P. Eckart and J. P. Ost. A dinner preceded the meeting. February 26. Attendance 160.

The Electron Theory in Modern Physics, by M. I. Pupin, National President, A. I. E. E. A dinner preceded the meeting. March 26. Attendance 450.

Saskatchewan

Rural Telephone Development in Saskatchewan, by W. J. Patterson, Minister of Telephones, and

The History of the Telephone, by J. D. Pearl, Northern Electric Co. A motion picture, entitled "From Mine to Consumer," was also shown. March 25. Attendance 125.

Schenectady

Transmission of Pictures by Wire, by B. K. Rhodes, New York Telephone Co. Illustrated with slides. March 12. Attendance 350.

Refrigerators, by A. R. Stevenson, General Electric Co. March 26. Attendance 350.

Seattle

The Development of Sub-Station Practises, by Joseph Hellenthal, Puget Sound Power and Light Co. Illustrated with slides. March 17. Attendance 43.

Sharon

Behind the Scenes, a demonstration presented by the Bell Telephone Co. March 26. Attendance 500.

Among the Fjords of America, by L. O. Armstrong. Illustrated with slides and moving pictures. April 6. Attendance 503.

Spokane

Results of National Survey of Engineering Education, by H. V. Carpenter, State College of Washington. March 19. Attendance 31.

Springfield

The Manufacture of Incandescent Lamps, by H. W. Crafts, General Electric Co. Illustrated with slides and a film. January 25. Attendance 66.

Methods of Medical Treatment of Interest to Electrical Engineers, by Dr. McIver Woody, Gilbert and Barker Mfg. Co. March 22. Attendance 60.

Toronto

Power Transformers, by C. A. Price, Canadian Westinghouse Co. Illustrated with slides. March 19. Attendance 115.

The Self-Propelled Unit Rail-Car, by R. J. Needham, Canadian National Railways. April 9. Attendance 52.

Urbana

Piezoelectricity: Its Scientific and Engineering Applications, by Prof. J. T. Tykociner, University of Illinois. March 11. Attendance 95.

Utah

The Evolution of the Dynamo, by B. F. Howard, Mountain States Telephone & Telegraph Co. March 24. Attendance 43.

Washington

Electrical Apparatus Applied to Dredging Operations, by H. C. Giroux. Illustrated. April 13. Attendance 41.

Worcester

Analogies in Mechanics and Electricity, by Prof. W. S. Franklin, Massachusetts Institute of Technology. March 31. Attendance 50.

BRANCH MEETINGS

Alabama Polytechnic Institute

Business Meeting. March 3. Attendance 23.

Opportunities of the Engineer outside of the Big Corporations, by Prof. Hill. A motion picture, entitled "Letting Dynamite Do It," was also shown. March 10. Attendance 24.

Railway Electrification, by C. E. Haynie, student, and

Orthophonic Reproduction, by J. A. Douglas. March 17. Attendance 18.

Banking and Banking Business, by Prof. A. L. Thomas. March 24. Attendance 26.

Engineering in the Big Cities, by R. O. Lyle, student, and

Rescue Methods of Submarinist, by S. L. Hancock, student. A motion picture, entitled "Beyond the Microscope," was shown. March 31. Attendance 23.

Early History of the Alabama Polytechnic Institute, by Dean John J. Wilmore. April 7. Attendance 19.

University of Arizona

Temperature Change in Induction Watt-Hour Meters, by B. Cottrell;

Elimination of Echoes in Long-Distance Telephone Sets, by T. E. Davis, and

Patents and Patent Laws, by D. M. Dexter. March 6. Attendance 20.

Temperature Rise in D-C. Machines, by Chas. Dunn, and

The Boston Tech Cooperative Course, by R. Fulton. March 13. Attendance 16.

Recent Telephone Development, by Mr. Guyman. March 20. Attendance 20.

Ethics, by Prof. Paul Cloke. Motion picture, entitled "Short Cuts to Quantity Production," was shown. March 27. Attendance 17.

Armour Institute of Technology

Artificial Resuscitation and First Aid, by Dr. J. T. McNamara. January 22. Attendance 101.

Electric Shovels, by M. T. Goetz, A. R. Waehner and C. W. Burcky, students. Illustrated with slides. A talk on the same subject was also given by A .A. Thompson, General Electric Co. February 18. Attendance 28.

Business Meeting. March 4. Attendance 27.

A motion picture, entitled "The King of the Rails," was shown. March 18. Attendance 54.

Brooklyn Polytechnic Institute

Home Lighting, by J. J. McMullan; *High-Frequency Radio Oscillations*, by Lloyd Goldsmith; *Public vs. Private Ownership of Public Utilities*, by Harry Walker; *Lord Kelvin*, by James Dalton and Dominic Chiarello, and *Regenerative Braking*, by Fred Wahlers. March 26. Attendance 25.

California Institute of Technology

A motion picture, entitled "The Story of Anaconda," was shown. March 9. Attendance 8.

A motion picture, showing the manufacture of high-tension cable by the Okonite process, was shown. March 31. Attendance 16.

Case School of Applied Science

General Motor Applications, by Mr. Rogers, General Electric Co. March 2. Attendance 64.

D-C. Engineering Applications, by Mr. Franklin, General Electric Co. March 9. Attendance 59.

Experiences of Student Engineers, by R. C. Putnam. April 7. Attendance 33.

Clemson Agricultural College

Group Versus Individual Motor Drive, by J. R. Cooper; *Electric Elevator Practise*, by B. D. King; *State-Owned Power Again*, by O. M. Harrelson; *Battling Bandits by Broadcasting*, by J. A. Warren, and *Current Events*, by R. H. Mitchell. March 4. Attendance 18.

University of Colorado

Radio Wave Propagation, by Mr. Cassel. April 7. Attendance 50.

Cooper Union

Motion pictures, entitled "Speeding Up Our Deep-Sea Cables," "Telephone Inventors of Today," and "Putting a Telephone Together with Trick Photography," were shown. March 27. Attendance 46.

University of Denver

Principles of the Watt-Hour Meter and Testing, by R. R. McLaughlin, and

The Auto-Valve Lighting Arrester, by A. R. Bitter. March 26. Attendance 16.

The Evolution of the Dynamo, by H. T. Howard, Bell Telephone Co. Illustrated with slides. April 9. Attendance 30.

University of Florida

High-Frequency Alternators, by J. W. Graff. March 22. Attendance 8.

Georgia School of Technology

Motion pictures, entitled "The Wizardy of Wireless" and "Beyond the Miscroscope," were shown. March 23. Attendance 58.

University of Idaho

Motion picture, entitled "Yoke of the Past," was shown. March 16. Attendance 31.

State University of Iowa

Automatic Control for Power Stations, by E. J. Hoetman;

Electric Signs, by P. W. Hubbard, and

Phototelegraphy, by P. A. Loyet. March 10. Attendance 42.

The Value of Student Branches to Engineering Societies, by Prof. W. H. Kavanaugh, University of Pennsylvania. March 17. Attendance 73.

An illustrated talk was given by Dean W. G. Raymond on a report from The Society for the Promotion of Engineering Education. Joint meeting with A. S. M. E. and A. S. C. E. March 31. Attendance 41.

A motion picture, entitled "The Insulation of Wires and Cables," was shown. April 7. Attendance 42.

Kansas State College

Choosing Your Vocation, by Mr. Reece, Bell Telephone Co. Match 25. Attendance 89.

University of Kansas

Synchronous Machines, by Mr. Henningson, General Electric Co. A motion picture on the Okonite process of insulation was shown. March 4. Attendance 75.

The General Electric Test, by A. Havenhill, General Electric Co. Illustrated. March 18. Attendance 65.

Lafayette College

Inspection trip to the Easton Central Office of the Lehigh Telephone Co. March 24. Attendance 20.

Massachusetts Institute of Technology

Water Power Developments in the United States, by Col. William Kelly, Technical Director, N. E. L. A. April 2. Attendance 20.

Michigan State College

Advantages at the General Electric Company of a Tester, by Professor Cory; *The Educational Advantages of the Westinghouse Company and the New York Edison Co.*, by Prof. Naeter; *The Advantages of the Telephone Business from the Educational Standpoint*, by Mr. Osborn, and *The Engineer in Public Utility Work*, by Prof. Kinney. February 25. Attendance 35.

Milwaukee School of Engineering

A motion picture, entitled "The Life of Thomas A. Edison," was shown. March 23. Attendance 30.

Motion pictures, entitled "The Westinghouse Plant" and "The Story of Dynamite," were shown. April 7. Attendance 31.

Montana State College

Fifty Years of Service, by Thomas Neal, and

Railway Electrification Progress During 1925, by H. K. Miller. March 15. Attendance 149.

Development of Electric Lighting, by J. C. Lorimer, General Electric Co., April 1. Attendance 139.

University of Nebraska

Business Meeting. March 5. Attendance 32.

Motion picture, entitled "Temperature and Motor Endurance," was shown. April 1. Attendance 40.

University of Nevada

Meters and Lightning Arresters, by W. C. Smith, General Electric Co. Motion pictures on the life of Thomas Edison were also shown. March 17. Attendance 44.

College of the City of New York

Business Meeting. March 11. Attendance 15.

New York University

Opportunities with the General Electric Company, by Mr. Rugan. Illustrated with moving pictures. March 25. Attendance 53.

University of North Dakota

Pioneers in the Electrical Industry, by Nels Anderson, student,

Rural Transmission Lines, by O. B. Medalen, student, and

The Brunswick Panatrope, by George Russ, student. March 22. Attendance 20.

Northeastern University

Wire Cable and Insulation, by C. D. Davis, Simplex Wire and Cable Co. March 25. Attendance 25.

Ohio Northern University

Business Meeting. March 24. Attendance 36.

Business Meeting. The following officers were elected: Chairman, M. Heft; Vice-Chairman, A. Mathews; Secretary, L. Wadsworth; Treasurer, K. Heming. March 31. Attendance 36.

Ohio State University

Talk by C. F. Kettering, President, General Motors Research Corp. February 26.

Dinner Meeting, at which C. S. Coler, Westinghouse Elec. & Mfg. Co., spoke. March 10.

Developments in the Telephone World, by C. P. Cooper, Ohio Bell Telephone Co. March 12. Attendance 88.

Ohio University

Power Rates and Methods of Fixation, by F. M. McKay, Southern Ohio Power Co. The following officers were elected: President, N. R. Smith; Vice-President, Frank Morgan; Secretary, J. E. Quick; Treasurer, T. R. Root. March 18. Attendance 17.

Oklahoma Agricultural and Mechanical College

The Field of Engineering, by Prof. Edward Kurtz. The following officers were elected: President, W. J. Beckett; Vice-President, Hal Horton; Secretary, Lee Rogers. February 17. Attendance 25.

Business Meeting. Moving picture of Yellowstone Park was shown. March 10. Attendance 47.

Motion pictures, entitled "The Wizardy of Wireless," "The Audion," "Via Radio," and "The Spirit of Service," were shown. April 7. Attendance 80.

University of Oklahoma

Business Meeting. February 25. Attendance 15.

University of Pittsburgh

Public Utilities as a Field for Engineers, by M. R. Scharf, Duquesne Light Co. February 12. Attendance 35.

Engineering Education, by James G. Pattillo, student, and

The Philadelphia Company, by James H. Hoffman, student. February 19. Attendance 29.

Purdue University

Automatic Elevator Control, by R. C. Parker. A motion picture, entitled "Insulation," was also shown, followed by a talk by Prof. Alfred Still. March 30. Attendance 20.

Rensselaer Polytechnic Institute

Automatic Train Control, by W. H. Reichard, General Railway Signal Co. Illustrated with slides. March 17. Attendance 175.

Rhode Island State College

The Electric Clock to be Made Universal, by Mr. Larson; *Mercury-Steam Turbine Generators*, by Mr. Rolston, and *Marine Electric Installations*, by Mr. Wilbourn. March 1. Attendance 15.

The Narragansett Electric Light Plant, by F. R. Smith. March 15. Attendance 17.

Rutgers University

Imagination in Engineering, by H. C. Powell, and

Manufacture of Electrical Porcelain, by Mr. Henderson. March 8. Attendance 21.

University of Southern California

Recent Developments of the General Electric Co., by Mr. Hill. March 4. Attendance 19.

Syracuse University

High-Frequency Induction Furnaces, by N. C. Reed. March 1. Attendance 19.

Long-Distance Transmission, by W. H. Schmidt. March 8. Attendance 18.

Hydrogen as a Cooling Medium, by R. F. Pearson. March 15. Attendance 19.

Voltage Regulators, by R. H. Watkins. March 29. Attendance 18.

Texas Agricultural and Mechanical College

Safety First, by R. K. Eason, student, and

Problems Confronting the Telephone Companies in Large Cities, by C. A. Richardson. March 19. Attendance 51.

University of Texas

Business Meeting. The following officers were elected: President, A. B. Atkinson; Vice-President, V. J. Graham; Secretary-Treasurer, T. S. Gray, and Corresponding Secretary, J. D. McFarland. March 25. Attendance 10.

Virginia Military Institute

Requirements for Recording and Reproducing Sound, by F. M. Barberie, and

Subterranean Heat as a Source of Energy, by R. W. Bouldin. March 16. Attendance 43.

Interior-Frosted Lamps and Corrugated Bulbs, by H. B. Bringhurst;

Training the Staff for Operating the Modern Power Plant, by J. O. Neville, and

Opportunities for the Technical Man in the Pittsburgh District, by J. S. Jamison. April 7. Attendance 46.

State College of Washington

Transformers, by Professor R. D. Sloan. Illustrated with slides. April 1. Attendance 73.

University of Wisconsin

Self-Starting Synchronous Motors, by S. H. Mortensen, Allis-Chalmers Mfg. Co. The following officers were elected: Chairman, Benjamin Teare; Secretary-Treasurer, Neal B. Thayer. March 23. Attendance 52.

Worcester Polytechnic Institute

The Land of Buddha, by Prof. H. B. Smith. Illustrated with slides. March 29. Attendance 45.

University of Wyoming

Business Meeting. April 7. Attendance 16.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers cooperating with the Western Society of Engineers. The service is available only to their membership, and is maintained as a cooperative bureau by contributions from the societies and their individual members who are directly benefited.

Offices:—33 West 39th St., New York, N. Y.,—W. V. Brown, Manager.

53 West Jackson Blv'de., Room 1736, Chicago, Ill., A. K. Krauser, Manager.

57 Post St., San Francisco, Calif., N. D. Cook, Manager.

MEN AVAILABLE.—Brief announcements will be published without charge but will not be repeated except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 33 West 39th Street, New York City,*** *and should be received prior to the 15th of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription rate of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by nominal contributions made within thirty days after placement, on the basis of $10 for all positions paying a salary of $2000 or less per annum; $10 plus one per cent of all amounts in excess of $2000 per annum; temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above, will it is hoped, be sufficient not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case, with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

POSITIONS OPEN

ELECTRICAL SALES ENGINEER, for company manufacturing carbon brushes and generators, and carbon specialties. Locations, Kansas City, and Birmingham, Alabama. R-9391-C.

EXPERIENCED TRANSFORMER ENGINEER, familiar with design and practice relating to high-tension, transformers and high-tension, small distribution and special purpose transformers. Must be capable of original work, both theory and practise. Position with a new division of an old line manufacturing company not previously engaged in the manufacture of high-tension electrical apparatus. R-9452.

SALES ENGINEER, to take on line of established renewal products. Must have acquaintances among the engineers of power railway and industrial companies. Exclusive territories in Philadelphia, Pittsburgh, Chicago, Pacific Coast, Buffalo, St. Louis, and Atlanta. R-9511-C-S.

SALESMAN, 25-35, electrical engineering education, who has had experience preferably with one of the large electrical manufacturing companies in the design and sale of electric motors and generators and who has had sales experience. The work will be development of the use of roller bearings in electric motors and generators, and sale of bearings in this market. Considerable traveling necessary. Apply by letter. Headquarters, New Jersey. R-8616-C.

ENGINEER, 30-40, who has had experience as production and schedule engineer in industrial or public utility work. Must be able to plan and direct work of schedule division of engineering department, including the progress and schedule of engineering and construction work, time study, budget records, and production control. Apply by letter. Location, Pa. R-9403-C.

ELECTRICAL ENGINEER, experienced on design transformers. Work will be on electrical welding transformers. Salary $200-$250 a month. Apply by letter. Location, Chicago. R-9157-C.

SALES ENGINEER, to handle distribution and power transformers on salary basis. Must be familiar with public utilities and be resident of Pennsylvania. Apply by letter. Headquarters, Pennsylvania. R-9454.

MEN AVAILABLE

GRADUATE OF M. I. T., 1924, in electrical engineering, age 26. Four months Western Electric Company, sixteen months Telephone Company. Desires position electrical engineering work. New England preferred, but will go anywhere. Salary approximately $35 a week. Available immediately. C-1045.

ELECTRICAL ENGINEER, age 29, with thorough technical education, desires position with consulting firm or public utility, preferably in the West. Three years teaching electrical engineering and four years' experience in test, sales and engineering with General Electric Company. Familiar with power transmissions and related fields. Available after June 15th. C-1118.

GRADUATE ELECTRICAL AND MECHANICAL ENGINEER, desires permanent position engineering work Pacific Coast. Two years drafting, designing with electrical manufacturing company, two years substation design, rate engineering large public utility. Good character, pleasing personality, efficient worker; several languages; European university graduate; 27, married. Minimum salary $175.00 a month. Present employed. Available month's notice. C-1109.

RADIO ENGINEER, thoroughly educated, experienced, wants position technical correspondent or development engineer large radio company. Past four years employed as operating engineer, second in charge, in two of New York's broadcasting stations. Designed, constructed, installed a third large broadcasting station Second Radio District. Two years' magazine, special feature writing experience. Not interested position broadcasting station. Available two weeks' notice. Minimum salary $3000. C-1108.

ELECTRICAL ENGINEER, age 27, single, 1923 graduate. Experience with public utilities on the construction, maintenance and operation of transmission and distribution systems. Also familiar with the routine clerical work of both central and district offices. Desires position as electric supervisor, or position leading to executive responsibility. Available on short notice. Location immaterial. B-9897.

ELECTRICAL ENGINEER, college graduate, B. S. degree in E. E., age 29, single. Two and one-half years' Westinghouse test, one month electrical maintenance work in large factory, seven and one-half years' experience electrical construction and supervising work in power houses, substations and transmission lines. Location anywhere in the United States, preference West. Available on week's notice. B-7637.

ELECTRICAL AND MECHANICAL ENGINEER, graduate with honors. G. E. Test, switchboard and central station engineering department; experienced shops, drafting, design and layouts H. T. transmission and protective gear. Desires operating experience with power company. Available May. Location immaterial. B-7623.

ELECTRICAL ENGINEER, four years' design and development experience with large manufacturing company. Would like similar work with a well established company in the Middlewest. College graduate, 28, married. C-1132.

SALES ENGINEER, age 34, married, well acquainted with New England markets, desires to represent electrical manufacturer in this territory. Experienced in selling to dealers, jobbers and manufacturers. Technical education, ten years' engineering and selling experience. Present connection with internationally known manufacturer. Salary and expenses. Available one month. A-1330.

ELECTRICAL ENGINEER, age 32, married, twelve years' experience power plant, substation, industrial, construction, operation, etc., four years with Westinghouse, power plant, substation, switching, metering, drafting, design, control and servicing engineer, eight years industrial and public utilities. Desires engineering, drafting, or supervision in greater New York. Available immediately. B-3172.

SALES ENGINEER-ASSISTANT ENGINEER, married, technical graduate in electrical engineering. Experienced distribution (AC or DC) high voltage transmission, power station design, power systems, also experienced field work and taking off an inventory, and inspection of electrical goods, cable, wire and materials, experience in radio reception, transmission and de-

sign. Good sales personality, convincing talker, thorough workman. B-6558.

ELECTRICAL ENGINEER AND PHYSICIST, age 34, graduate of several leading universities, on instruction staff of well known institution for five years, also commercial experience. Extensive work in electrical and radio development, also patent experience. Position in electrical development, patent work, or with public utility desired. Location. East. B-165.

ELECTRICAL-MECHANICAL DRAFTSMAN, age 27, married, technical education, field and office experience on machinery and power house construction. Available immediately. Anywhere. B-7666.

ENGINEER, E. E., desires position with consulting engineer in industrial development, or as professor. Fifteen years' responsible university positions, including charge of electrical and physics laboratories, development, project, analysis, commercial tests; editorial experience; specialist in illumination. Wants opportunity with future prospects, utilizing broad education, general experience and mature powers. B-2824.

ELECTRICAL ENGINEER, age 33, married, ten years electrical construction experience, desires position as superintendent, or assistant to general manager of construction. Experienced in construction of transmission lines, both overhead and underground, automatic and manually operated high tension substations. Diversified experience in sugar mill and malleable iron foundry practise. At present employed, best of references. Minimum salary $3000. A-3191.

ELECTRICAL ENGINEERING, GRADUATE, age 27, married, two years' commercial and engineering experience with telephone and power companies, one year teaching experience as instructor of electricity and mechanical drawing in vocational department of high school. Desires temporary employment. Available June 20th. B-7028.

EXECUTIVE—A man trained as an engineer, experienced as a factory manager, seeks connection offering opportunity for development. Manufacturing experience covers fifteen years on varied line of electrical products. Possesses vision, initiative, tact and the ability to organize an economical factory administration. Salary and percentage bonus based on results preferred. C-1102.

WANTED position as superintendent of power. Fourteen years' experience in construction, operation and maintenance of power plants and transmission systems. Willing to go anywhere in the United States. Available on one month's notice. C-1152.

RECENT GRADUATE ELECTRICAL ENGINEER, desires part time work, designing, estimating, checking, or calculating. Experience in steam power plant electrical construction, also on transmission line survey. Location, Philadelphia. C-1180.

ELECTRICAL ENGINEERING GRADUATE, age 23, single, with one and one-half years electrical testing, and one and one-half years electrical drafting, desires position as electrical draftsman on power plants, or industrial buildings. Location, East. B-6790.

INDUSTRIAL ELECTRICAL ENGINEER, technical graduate, married, wide experience design, repair, construction of electrical equipment as applied to industrial plants, also power plant construction. Desires position with large industrial plant as industrial electrical engineer. Location, Central States. Available on reasonable notice. C-1194.

ELECTRICAL ENGINEER, graduate 1921, desires position with engineering or industrial concern where rapid promotion depends on ability only. Broad experience, operating and distribution problems, industrial electrification, high tension laboratory. At present foreman for test division with leading public utility. Available on two weeks' notice. Age 32, married. Minimum salary $2700. C-1190.

ELECTRICAL ENGINEER, capable graduate E. E., age 29, single. Has had one year's experience on the General Electric Company test, and five years in distribution engineering and construction work. Has specialized in underground engineering and am thoroughly familiar with A. C. low voltage network systems. Has also had considerable experience with electrolysis mitigation. Location immaterial. Available on short notice. C-1191.

EXECUTIVE-MACHINE TOOL ENGINEER, age 38, with all round designing, manufacturing and selling experience, desires connection with eastern company that can take on the manufacture of a semi-automatic production machine. Salary $5500 plus commission or royalty to be arranged. B-9603.

ELECTRICAL AND MECHANICAL ENGINEER, age 40, married, technical university graduate. Fifteen years of practical experience in design, test and operation of A. C. and D. C. motors, generators and switchboard panels; elevator construction, hoisting equipment and installations. Development and production work. Available on reasonable notice. Location, New York City or vicinity. B-5240.

ASSISTANT PROFESSOR OF ELECTRICAL ENGINEERING, age 39, married, desires promotion to associate or full professorship in Middle Atlantic or Midwestern university. Initiative. An all around good teacher. Prefers the advanced subjects. Mathematician. Reading knowledge of German and French. Bachelor's and Master's degrees. Ten years' teaching, three years' practical experience. Salary $3250 to $4000. B-2663.

PATENT ATTORNEY, age 24, electrical engineer, having three years' experience in the Patent Office handling both electrical and mechanical cases, desires to locate with a patent attorney, or with a large manufacturing company in the vicinity of Chicago. C-610.

MANAGER OR EXECUTIVE, age 43, married, seventeen years' electrical experience successful in managing and operating electrical public utility; especially successful in dealing with the public. Desires position in larger field. Salary $6000. C-1179.

ELECTRICAL ENGINEER, fifteen years' experience, mostly in design of alternating current machines. Post graduate technical education. Has done responsible developmental work on transformers, induction motors, direct current motors and new and unusual apparatus. Considerable executive experience. Capable of handling difficult technical problems. Position as executive or responsible technical engineer desired. C-1181.

RAILWAY TELEGRAPH AND TELEPHONE ENGINEER, 36, British, ten years' experience, (also as superintendent), all modern systems, selector, electric staff, condenser-impulse telegraphy, etc. Specialist difficult country. Available May on completion modernization entire system. Desires charge of similar modernization, two or three years, or would accept shorter contract to inspect and recommend with specifications. Location, outside of United States. Fluent French, Spanish. C-2009.

YOUNG MAN, graduating from B. P. I. in electrical engineering, desires a position with an electrical manufacturer or public utility. Especially interested in the field of illumination. Will consider any place that has a chance for advancement. Location, New Jersey or New York City. C-1173.

ELECTRICAL-MECHANICAL ENGINEER, technical graduate, desires connection with contracting or consulting engineering firm contemplating forming an electrical department. Experienced in power and substation design and industrial engineering. At present rehabilitating public utility in South America. C-1141.

ELECTRICAL ENGINEER, desires position as operating or distribution engineer. Age 27, married, technical education. Two years G. E. test, three years electrical superintendent of large industrial plant, and two years with utility company serving 12,000 customers as distribution engineer. Salary $225. Available two weeks' notice. B-9390.

ASSISTANT TO GENERAL ELECTRICAL SUPERINTENDENT of large public utility, available on reasonable notice. Eight years' experience general utility problems, budgets valuations, statistics, accounting, economical engineering investigations, operating problems, high voltage transmission, communication, safety, personnel matters. Sc. B., E. E. degrees, 30, married. Desires permanent position in satisfactory location offering opportunity for advancement. B-3311.

ELECTRICAL ENGINEER, age 27, single, Marquette University graduate 1925, desires opportunity in hydro-electric work. Expects to combine study with work entered. Location immaterial. C-1162.

GRADUATE ELECTRICAL ENGINEER, age 28, married, varied experience in maintenance, drafting, sales engineering, commercial work and operating public utility system. Desires position as assistant manager or superintendent with public utility, or engineer with manufacturing company. Employed at present. Available in thirty days. Location, East Central Atlantic States. Minimum salary $200 a month. B-7827.

ELECTRICAL CONSTRUCTION SUPERINTENDENT, age 38, wide experience electrical construction, operation; ten years construction, eight years general superintendent railways, power plants, substations, general utility work. Present on contract for electrical construction in foreign service. Prefers connection with railway or electrical concern as representative in Latin countries. Technical training. Speaks Spanish, English. Available on five months' notice. C-886.

SALES ENGINEER, who has large acquaintance in the Southern states. Capable of handling any line of heavy apparatus in this district. C-1211.

ELECTRICAL ENGINEER, 27, energetic, inventive and tactful. Past experience; electrical testing and charge of electrical testing apparatus and research, good references. Desires position developing and research of electrical apparatus or machinery. At present employed, but available on two weeks' notice. Greater New York preferred. B-7270.

SALES MANAGER, for manufacturer desiring business relations with central stations and holding companies. Age 39, clean cut aggressive sales engineer with record of sales achievement in public utility field. Graduate engineer. Available in sixty days. Highest references. B-4221.

PROFESSOR IN ELECTRICAL ENGINEERING desired by Harvard University graduate with thirteen years' university teaching experience, and five years of varied and valuable practise, in addition to numerous summers' work. Specialist in high voltage transmission research, theory, design and practise. Important experience with both Westinghouse and G. E. Companies. 43, married, excellent health. C-577-2-C-15.

RADIO ENGINEER AND PRODUCTION MANAGER is open for a connection. For past three years has been acting in those capacities for a well known manufacturer. College education, proven executive ability, clear grasp of audio and radio fundamentals. Well known among the trade fraternities. Best references given and asked for. C-1020.

ELECTRICAL ENGINEER, 33, married, fourteen years' experience design and manufacture electric heating devices, and small specialties, incandescent lamp manufacture, power plant location and finance. Has direct access to large capital for any good proposition in South America and connections in South. Location, Pacific Coast or South America. C-1177-4-A-3.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

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*WHITE, HARRISON GATES, Sales Engineer, Mancha Storage Battery Locomotive Co., 1909 S. Kingshighway Blvd., St. Louis, Mo.
WILFLEY, VERNON BAILEY, Electrical Engineer, Westinghouse Elec. & Mfg. Co., Wilkinsburg, Pa.
WILKINSON, THOMAS ALEXANDER, General Engineer, Westinghouse Elec. & Mfg. Co., 150 Broadway, New York, N. Y.
*WILLIAMS, F. REID, Engineer, Dixie Power Co., Cedar City; for mail, Veyo, Utah.
*WILLIAMSON, ROBERT BLANCHARD, Field Engg. Work, General Railway Signal Co., Rochester, N. Y.
WITTENBERG, ALBERT J., General Foreman, Brooklyn Edison Co., Inc., 14 Rockwell Place, Brooklyn, N. Y.
*WOLF, ALEXANDER, Investigation & Research Section, Philadelphia Electric Co., Philadelphia, Pa.
*WOODWARD, JOHN EGGLESTON, Student Engineer, Standard Oil Co. of New Jersey, Bayway Refinery, Elizabeth, N. J.
*WURST, LEROY LAWRENCE, Field Engineer, Public Service Co. of Northern Illinois, 198 N. Schuyler Ave., Kankakee, Ill.
WYATT, RALPH M., Methods Engineer, Western Electric Co., Inc., 268 W. 36th St., New York, N. Y.
YOUNG, THOMAS JOSEPH, Member, Technical Staff, Research Dept., Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.
ZELLWEGER, F., Asst. to Electrical Engineer, Schweitzer & Conrad, Inc., 4421 Ravenswood Ave., Chicago, Ill.
*ZIMMERMANN, ANDREW GEORGE, Switchboard Engineer, The Pacific Tel. & Tel. Co., 140 New Montgomery St., San Francisco, Calif.

Total 205

*Formerly enrolled students

ASSOCIATES REELECTED APRIL 9, 1926

BROWN, EDWARD CLAUDE, Consulting Engineer, Edward C. Brown Co., 200 Devonshire St., Boston, Mass.
HACKBUSCH, RALPH ANTHONY, Service Dept., Canadian Westinghouse Co., Ltd., 366 Adelaide St., W., Toronto, Ont., Can.

MEMBER ELECTED APRIL 9, 1926

ZELENTSOFF, JICHAEL EUGENE, Professor, Electrotechnical Institute, Pessochnaia 7, Leningrad, Russia.

FELLOW ELECTED APRIL 9, 1926

CHERNYSHOFF, ALEXANDER, Professor, Polytechnic Institute, Leningrad, Sosnowka, Russia.

TRANSFERRED TO GRADE OF FELLOW APRIL 9, 1926

FLEAGER, CLARENCE E., Chief Engineer, Pacific Telephone & Telegraph Co., San Francisco, Calif.

TRANSFERRED TO GRADE OF MEMBER APRIL 9, 1926

CLARK, JOHN A., Research Engineer, Weston Electrical Instrument Corp., Newark, N. J.
CUNNINGHAM, R. E., Operating Electrical Engineer, Southern California Edison Co., Los Angeles, Calif.
DAVIES, HAROLD C., Station Section, Elec. Engineering Dept., Hydro Electric Power Commission, Toronto, Ont., Can.
FIELDS, ERNEST S., Asst. Electrical Engineer, Union Gas & Electric Co., Cincinnati, O.
GRAHAM, FRANK H., Telephone Engineer, Bell Telephone Laboratories, New York, N. Y.
HALE, WILLIAM K., State Electrical Engineer, Mountain States Tel. & Tel. Co., Denver, Colo.
HARRIS, IRVING C., Consulting Engineer, Cone and Harris, Los Angeles, Calif.
HEALY, EDWIN S., Transmission Engineer, Electric Bond & Share Co., New York, N. Y.
HINSON, N. B., System Planning Engineer, Southern California Edison Co., Los Angeles, Calif.
HORN, A. F. E., Manager, General Electric Co., Washington, D. C.
JOHNSON, JAMES A., Works Manager, Canadian Crocker Wheeler Co., Ltd., St. Catherines, Ont., Can.
JONES, ARTHUR L., District Engineer, General Electric Co., Denver, Colo.
PUBLOW, CEDRIC F., Asst. Station Engineer, Hydro Electric Power Commission, Toronto, Ont., Can.
SIMPSON, WILLIAM L., Division Engineer, Postal Telegraph-Cable Co., Chicago, Ill.
SOULE, WILLIAM H., Electrical Superintendent, Mond Nickel Co., Coniston, Ont.
STARR, JAMES H., District Engineer, Condit Electrical Manufacturing Co., St. Louis, Mo.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting held April 5 and 26, 1926, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the National Secretary.

To Grade of Fellow

BEDELL, FREDERICK, Professor of Applied Electricity, Cornell University, Ithaca, N. Y.
BOYAJIAN, ARAM, Electrical Engineer, General Electric Co., Pittsfield, Mass.
DAVIDSON, WARD F., Research Engineer, Brooklyn Edison Co., Brooklyn, N. Y.
MARRIOTT, ROBERT H., Consulting Engineer, New York, N. Y.
McQUARRIE, JAMES L., Chief Engineer, International Standard Electric Corp., London, England.
ORSETTICH, ROBERT, Chief Engineer, Wilton Works of General Electric Co., Birmingham, England.
RICHARDS, WILLIAM E., Supt., Electrical Dept., Toledo Edison Co., Toledo, Ohio.
THOMAS, GEORGE N., Contract Engineer and Supt. of Construction, Canadian General Electric Co. Ltd., Toronto, Ontario.

To Grade of Member

BULLARD, WILLIAM R., Assistant Engineer, Electric Bond & Share Co., New York, N. Y.
CAMPBELL, THADDEUS C., Telephone Engineer, Systems Development Dept., Bell Telephone Laboratories, New York, N. Y.
HENTZ, ROBERT A., Electrical Engineer, Philadelphia Electric Co., Philadelphia, Pa.
HODTUM, JOSEPH B,, Sales Engineer, Pittsburgh, Transformer Co,, Pittsburgh, Pa,
HULL, BLAKE D., Transmission & Protection Engineer, Southwestern Bell Telephone Co., St. Louis, Mo.
KEPHART, CALVIN I., Senior Examiner (Valuation), Interstate Commerce Commission, Washington, D. C.
KNUDSEN, H. A., Electrical & Mechanical Engineer, East Bay Municipal Utility District, Oakland, Calif.
KOCH, M. McK., Supt. Electric Distribution, Public Service Co. of Colorado, Denver, Colo.
LOUIS, H. C., Chief of Research & Test, Consolidated Gas Electric Light & Power Co., Baltimore, Md.
MacNAUGHTON, A. K., Supt. of Distribution, Blackstone Valley Gas & Electric Co., Pawtucket, R. I.
McCLELLAN, LESLIE N., Electrical Engineer, U. S. Bureau of Reclamation, Denver, Colo.
McILVAINE, H. A., Engineer, Cleveland Vacuum Tube Works, Cleveland, O.
McROBBIE, HENRY W., Supt. Substations, West Penn Power Co., Connellsville, Pa.
NELSON, EDWARD L., Engineer, Bell Telephone Laboratories, New York, N. Y.
NORRIS, ERIC D. T., Technical Electrical Engineer, Ferranti Ltd., Hollinwood, Lancashire, England.
SIMONS, DONALD M., Development Engineer, Standard Underground Cable Co., Pittsburgh, Pa.
SIMS, WILLIAM F., Field Engineer, Generating Stations, Commonwealth Edison Co., Chicago, Ill.
STEBBINS, ALDEN H., Electrical Engineer, Edward Ford Plate Glass Co., Rossford, Ohio.
STINER, H. WRAY, Commercial Engineer, General Electric Co., Cleveland, O.
THOMAS, HERBERT P., Chief Engineer, Southland Electric Power Board, Invercargill, N. Z.
VAN BOKKELEN, WILLIAM R., Chief Engineer, Coast Counties Gas & Electric Co., San Francisco, Calif.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before May 31, 1926.

Alexander, R. W., Commonwealth Power Corp., Jackson, Mich.
Allison, R. S., Niagara, Lockport & Ontario Power Co., Avon, N. Y.
Ambrose, L. O., The Austin Co., Cleveland, Ohio

Anderson, H. L., Commonwealth Power Corp., Jackson, Mich.
Andrews, C. L., The Pacific Tel. & Tel. Co., Portland, Ore.
Anson, E. H., Gibbs & Hill, New York, N. Y.
Anthony, R. B., Penna. Power & Light Co., Mt. Carmel, Pa.
Arbuckel, J. S., American Brown Boveri Electric Corp., Camden, N. J.
Atkinson, J. N., Newfoundland Power & Paper Co., Ltd., Deer Lake, Newfoundland
Atwood, D. S., Llewellyn Iron Works, Los Angeles, Calif.
Bass, O. B., Canadian Pacific Steamships, Ltd., Vancouver, B. C., Can.
Baudry, R. A. M., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Bell, C. R., Cleveland Electrical Illuminating Co., Cleveland, Ohio
Bird, C. A., (Member), The Detroit Edison Co., Detroit, Mich.
Bisazza, R., General Electric Co., Schenectady, N. Y.
Blanch, F. D., General Electric Co., Schenectady, N. Y.
Boura, F. G., West Penn Power Co., Pittsburgh, Pa.
Bowen, W. E., Great Western Power Co., San Francisco, Calif.
Boyer, W. A., General Electric Co., Schenectady, N. Y.
Bragg, A. D., General Electric Co., Schenectady, N. Y.
Branson, A. K., Great Western Power Co. of Calif., Oakland, Calif.
Bryarly, M. M., U. S. Veterans Bureau, Washington, D. C.
Buery, G. E., Peninsula Lumber Co., Portland, Ore.
Burt, A. R., Kansas City Railways Co., Kansas City, Mo.
Butler, M. B., Jr., (Member), American Chain Co., Bridgeport, Conn.
Butterfield, H. S., Atlantic City Electric Co., Atlantic City, N. J.
Campbell, A. E., The Ohio Power Co., Canton, Ohio
Chandler, W. G., Brooklyn Edison Co., Brooklyn, N. Y.
Cheney, W. E., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Clark, Sherman B., Northwestern Electric Co., Portland, Ore.
(Applicant for re-election.)
Cooper, W. J., Electrician, St. Paul's Hospital, Vancouver, B. C.
Costella, A. P., The Camden Storage Battery Co., Camden, N. J.
Cottrell, W. J., Allied Industries, Inc., Portland, Ore.
(Applicant for re-election.)
Crowell, R. M., Utah Power & Light Co., Salt Lake City, Utah
Damon, A. C., Simplex Wire & Cable Co., Cambridge, Mass.
Daugherty, T. C., New England Tel. & Tel. Co., Boston, Mass.
Davis, J. C., Jr., Edison Elec. Illuminating Co., Roxbury, Mass.
Davison, C., Mexican Telegraph Co., Orizaba, Verz Cruz, Mexico
Dean, C. P., Bell Telephone Laboratories, Inc., New York, N. Y.
de Celis, F., Mexican Light & Power Co., Mexico City, Mex.
Dedek, F. G., Burroughs Adding Machine Co., Detroit, Mich.
Dellinger, F. E., Los Angeles Gas & Electric Corp., Los Angeles, Calif.
Dennis, E. M., Bloedel Donovan Lumber Mills, Bellingham, Wash.
Dickerson, F. A., New York Telephone Co., New York, N. Y.
Dodds, V. G., Aluminum Co. of America, Philadelphia, Pa.
Dowdy, J. W., Electrician & Licensed Marine Engineer, San Francisco, Calif.
Dring, L. G., New York Telephone Co., New York, N. Y.
Drummond, A. J. United Gas Improvement Contracting Co., Philadelphia, Pa.
(Applicant for re-election.)
Eberhardt, P. W., Duquesne Light Co., Pittsburgh, Pa.
Edward, J. A., Hydro-Electric Power Station, Snoqualmie, Wash.
Ehrke, E. B., Pacific States Electric Co., Los Angeles, Calif.
Ellis, D. W., Beech Bottom Power Co., Power, W. Va.
Erickson, E. O., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Ewing, C., Louisville Gas & Electric Co., Louisville, Ky.
Fawcett, O. M., West Penn Power Co., Pittsburgh, Pa.
Feindel, A., New York Edison Co., New York, N. Y.
French, M. A., Charles H. Tenney & Co., Boston, Mass.
Gambitta, A. F., Research Work, 6 W. 28th St., New York, N. Y.
Gardner, E. W., The Pacific Tel. & Tel. Co., Portland, Ore.
(Applicant for re-election.)
Garretson, F. M., Jr., Cooper Hewitt Electric Co., Hoboken, N. J.
Garvin, J. S., (Member), Bell Telephone Labs., Inc., New York, N. Y.
Gauchet, C. E., General Electric Co., St. Louis, Mo.
Grant, A. J., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Gray, J. W., Ohio Northern University, Ada, Ohio
Greene, E. M., Commonwealth Edison Co., Chicago, Ill.
Greene, J. H., Sanderson & Porter, New York, N. Y.
Griffin, G. H., Union Carbide Co., Sault Ste Marie, Mich.
Hadley, G. F., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Haertlein, A., Duquesne Light Co., Pittsburgh, Pa.
Harnett, D. E., Pacent Electric Co., New York, N. Y.
Hartranft, A. C., Philadelphia Electric Co., Philadelphia, Pa.
Henderson, C. L., West Penn Power Co., Pittsburgh, Pa.
Henderson, E. W., Duquesne Light Co., Cheswick, Pa.
Hiltebeitel, J., with H. N. Crowder, Jr., Co., Allentown. Pa.
Hoefflin, A. S., Louisville Gas & Electric Co., Louisville, Ky.
Holtman, J. E., (Member), Westinghouse Elec. & Mfg. Co., Denver, Colo.
Houle, A. V., The New York Edison Co., New York, N. Y.
Hubbard, H. H., Brooklyn Edison Co., Brooklyn, N. Y.
Jarvis, M. M., Burroughs Adding Machine, Detroit, Mich.
Johnson, W. M., Portland Electric Power Co., Portland, Ore.
Judy, E. W., Duquesne Light Co., Pittsburgh, Pa.
Humphreys, D., Newfoundland Power & Paper Co., Ltd., Deer Lake, Newfoundland
Kane, M. P., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Kelly, O. D., West Penn Power Co., Pittsburgh, Pa.
King, J. J., The Pacific Tel. & Tel. Co., Portland, Ore.
Kirchhof, W. H., Philadelphia Rapid Transit Co., Philadelphia, Pa.
Knowles, H. S., Popular Radio Inc., New York, N. Y.
Kucher, A. A., (Member), Westinghouse Elec. & Mfg. Co., Chester, Pa.
Kuriyan, J., Jr., General Electric Co., Schenectady, N. Y.
Lavigne, F. A., Westinghouse Elec. & Mfg. Co., San Francisco, Calif.
Mabee, G. C., Murrie & Co., New York, N. Y.
MacKay, A. T., Western Electric Co., Boston, Mass.
Mathews, P. W., Duquesne Light Co., Pittsburgh, Pa.
Mathewson, D. E., Lockwood Greene & Co., Inc., New York, N. Y.
Matthews, R. F., 214 N. McDowell St., Raleigh, N. C.
McArn, D. G., (Member), Pittsburgh Transformer Co., Pittsburgh, Pa.
McCauley, W. M., Railway & Industrial Engineering Co., Pittsburgh, Pa.
McCreight, R., Jr., Leeds & Northrup Co., Philadelphia, Pa.
McGuire, P. T., Duquesne Light Co., Pittsburgh, Pa.
McIntosh, R. S., Cleveland Railway Co., Cleveland, Ohio
McKinley, J. G., Jr., West Penn Power Co., Connellsville, Pa.
McNairy, J. W., General Electric Co., Schenectady, N. Y.
Meister, M. H., Western Union Telegraph Co., St. Louis, Mo.
Mendelhall, W. H., West Penn Power Co., Pittsburgh, Pa.
Metz, W. R., Westinghouse Elec. & Mfg. Co., Pittsburgh, Pa.
Milke, G. N., Compania de Electricidad de Merida, S. A. Merida, Yucatan, Mex.
Minton, J. P., (Fellow), Consulting Engineer, New York, N. Y.
Mitchell, J. M., General Electric Co., Schenectady, N. Y.
Molter, D. W. C., West Penn Power Co., Pittsburgh, Pa.
Monroe, R. W., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Morphey, L. A., Northwestern Electric Co., Portland, Ore.
Moyers, C. G., West Penn Power Co., Pittsburgh, Pa.
Moyle, E., General Electric Co., Schenectady, N. Y.
Munton, J. D., Atlantic Refining Co., Philadelphia, Pa.
Murdock, H. W., General Electric Co., Inc., Schenectady, N. Y.
Muzsnay, V. G., Sanderson & Porter, Springdale, Pa.
Nelthorpe, F. A., Jr., Puget Sound Pr. & Lt. Co., Seattle, Wash.
Newcombe, J., with John Wanamaker, New York, N. Y.
Newton, LeR. F., Fairbanks-Morse Co., Portland, Ore.
Opsahl, A. M., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Orgell, C. G., United Gas Improvement Contracting Co., Philadelphia, Pa.
Paton, J., Jr., American Electrical Works, Phillipsdale, R. I.
Paulus, C. F., Cleveland Electric Illuminating Co., Cleveland, Ohio
Pearson, H. E., Pratt Institute, Brooklyn, N. Y.
Pedley, H. L., Commonwealth Edison Co., Chicago, Ill.
Phillips, E. L., (Member), E. L. Phillips & Co., New York, N. Y.
Pla, R. A., General Railway Signal Co., Rochester, N. Y.
Podgainy, C., Freed-Eisemann Radio Corp., Brooklyn, N. Y.
Powell, H. T., Louisville Gas & Electric Co., Louisville, Ky.
Pugh, G. C., West Penn Power Co., Pittsburgh, Pa.
Quinn, J. T., Jr., New England Tel. & Tel. Co., Cambridge, Mass.
Rankin, G. D., The Hartford Faience Co., Hartford, Conn.
Rasmussen, W., Tabulating Machine Co., San Francisco, Calif.
Rice, H. E., New England Tel. & Tel. Co., Boston, Mass.
Rorke, C. B., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Rosado, A., Havana Electric Railway, Light & Power Co., Havana, Cuba
Rosewater, E., A. H. Grebe & Co., Inc., Richmond, Hill, N. Y.

Ross, D. G., General Electric Co., Schenectady, N. Y.
Rudd, T. O., Kerite Insulated Wire & Cable Co., New York, N. Y.
Rupert, C. L., Duquesne Light Co., Pittsburgh, Pa.
Russell, F. W., Louisville Gas & Electric Co., Louisville, Ky.
Samson, D. R., (Member), Dodge Brothers, Inc., Detroit, Mich.
Sanchez, U. C., Compania de Electricidad de Merida, S. A., Merida, Yucatan, Mex.
Sasaki, T., Mass. Institute of Technology, Cambridge, Mass.
Schultz, C. F., Cleveland Railway Co.. Cleveland, Ohio
Sillers, T. G. A., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Sinderson, L. O., General Electric Co., Schenectady, N. Y.
Slater, W. F., with Osburn Monnett, Evanston, Ill.
Smith, J. R., Louisville Gas & Electric Co., Louisville, Ky.
Snow, E. C., Louisville Gas & Electric Co., Louisville, Ky.
Snyder, C., General Electric Co., Schenectady, N. Y.
Snyder, R. J., Brooklyn Edison Co., Brooklyn, N. Y.
Sorke, W. S., Bliss Electrical School, Washington, D. C.
Sprague, C. S., Purdue University, Lafayette, Ind.
Sproule, H. C., Philadelphia Electric Co., Philadelphia, Pa.
Szontagh, John R., General Electric Co., Philadelphia, Pa.
Tavenner, W. B., Graybar Electric Co., Los Angeles, Calif.
Thayer, H. C., Jr., General Electric Co., Schenectady, N. Y.
Thayer, R. C., Great Northern Railway Co., St. Paul, Minn.
Thompson, A. W., Philadelphia Electric Co., Pittsburgh, Pa.
Thomson, J. F. F., General Electric Co., Schenectady, N. Y.
Tienken, W. J., Jr., Pratt Institute, Brooklyn, N. Y.
Troxel, F. D., Sargent & Lundy, Inc., Chicago, Ill.
Walton, I. R., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Warner, C. W., General Electric Co., Schenectady, N. Y.
Watanabe, J. S., Mass. Institute of Technology, Cambridge, Mass.
Watson, S. C., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Weigand, W. F., Jr., Philadelphia Rapid Transit Co., Philadelphia, Pa.
Wellman, B., General Electric Co., Schenectady, N. Y.
West, J. I., The Litchfield Light & Power Co., Litchfield, Conn.
White, E., New England Tel. & Tel. Co., Boston, Mass.
Wickersham, W. R., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Wiltshire, A. J., Marvel Equipment Co., Cleveland, Ohio
Total 173

Foreign

Aiyangar, R. R., Sri Brahmavidyambal Elec. Supply Corp. Ltd., Ramachandrapuram, Trichinopoly Dist., S. India
Bagchi, S. K., Tata Iron & Steel Co., Jamshedpur, India
Belianinov, N., Electrotechnical Institute, Leningrad, Russia
Bentzon, C. E., Mascaron 530, Lima, Peru, S. A.
Bryant, E., Te Awamutu Electric Power Board, Te Awamutu, Auckland, N. Z.
Doberck, W. A., Andersen Meyer & Co., Ltd., Shanghai, China
Entee, F. D., Century Mills, Bombay, India
Geary, S. J., Municipal Electricity Dept., Christchurch, N. Z.
Hooker, J. F., Municipal Electricity Dept., Christchurch, N. Z.
Irwin, J. E., Chile Exploration Co., Chuquicamata, Chile, S. A.
Knight, H. W., Brimsdown Power Station, Brimsdown, Eng.
Kooken, J. R., Chile Exploration Co., Chuquicamata, Chile, S. A.
Lopez, C. E., Cia. Huanchaca de Bolivia, Pulacayo, Bolivia, So. America
Mehta, J. J., The Municipality of Bombay, Bombay, India
Paddock, W. G., Lucknow Municipal Water Works, Aish Bagh, Lucknow, India
Polivanoff, M. C., (Fellow), Technical High School, Moscow, Russia
Rayment, E. G., Bethlehem Steel Co., Dock Central, La Plata, Arg. Rep., S. Amer.
Taylor, F. W., Ferranti, Ltd., Hollinwood, Lancashire, Eng.
Varley, H., The Electric Motor & Stove Hiring Co., Ltd., Leeds, Yorkshire, Eng.
Total 19

STUDENTS ENROLLED

Adkins, Elmer, University of Florida
Bartels, William H., Michigan State College
Baum, Marc, Cornell University
Christoph, Karl J., Columbia University
Clark, John L., Northeastern Univ.
DesBrisay, Aretas W. Y., McGill University
Dresser, Willis R., Mass. Tech.
Eaton, Thomas J., Mass. Tech.
Fannon, Joseph L., Mass. Tech.
Feige, Norman G., Johns Hopkins Univ.
Fekas, Harry J., Mass. Inst. of Tech.
Foss, Kenneth L., Univ. of New Hampshire
Frost, Lore A., Univ. of New Hampshire
Gancarczyk, Adolph, Detroit Institute of Tech.
Hancock, Samuel L., Alabama Poly. Inst.
Henderson, Francis C., Tufts College
Hoglund, Ejnar C., Worcester Poly. Inst.
Holton, James L., Rensselaer Poly. Inst.
Hussey, Frank W., Univ. of New Hampshire
Knudson, Jack W., Jr., Univ. of Texas
Laning, Willard A., Jr., Bucknell Univ.
Lee, Yuk-Wing, Mass. Tech.
Maynard, Leo H., Univ. of New Hampshire
McMaster, John E., Mass. Tech.
Menger, Francis, Univ. of Texas
Ogden, Samuel B., Columbia Univ.
Peterson, Clarence E., Washington State College
Peterson, Enar F. E., Northeastern Univ.
Rogers, Lee, Oklahoma A. & M. College
Russell, Walter H., Oregon State Agri. College
Shaheen, Shahady, Mass. Inst. of Technology
Sickel, Horatio G., Columbia Univ.
Stevenson, Archibald E., Cornell Univ.
St. James, Louis N., Cornell University
Stonefield, John W., Northeastern Univ.
Van Liddle, Newlee, Washington State College
Woehr, William A., Detroit Inst. of Tech.
Total 37

LIST OF SECTIONS

Name	Chairman	Secretary
Akron	Ralph Higgins	John Grotzinger, 64 Marguerite Ave., Cuyahoga Falls, Ohio
Atlanta	W. E. Gathright	W. F. Oliver, Box 2211, Atlanta, Ga.
Baltimore	W. B. Kouwenhoven	R. T. Greer, Madison St. Building, Baltimore, Md.
Boston	J. W. Kidder	W. H. Colburn, 39 Boylston Street, Boston, Mass.
Chicago	Carl Lee	B. E. Ward, Room 1679, 230 S. Clark St., Chicago, Ill.
Cincinnati	H. C. Blackwell	E. S. Fields, Union Gas & Electric Co., Cincinnati, Ohio
Cleveland	Chester L. Dows	J. F. Schnable, 3503 Mapledale Ave., Cleveland, Ohio
Columbus	R. J. B. Feather	W. T. Schumaker, 25½ North High St., Columbus, Ohio
Connecticut	A. A. Packard	A. E. Knowlton, Dunham Laboratory, Yale University, New Haven, Conn.
Denver	V. L. Board	R. B. Bonney, Telephone Building, P. O. Box 960, Denver, Colo.
Detroit-Ann Arbor	G. B. McCabe	Harold Cole, Detroit Edison Co., 2000 Second Ave., Detroit, Mich.
Erie	H. J. Hansen	L. H. Curtis, General Electric Co., Erie, Pa.
Fort Wayne	E. L. Gaines	D. W. Merchant, General Electric Co., Fort Wayne, Ind.
Indianapolis-Lafayette	H. M. Anthony	J. B. Bailey, 48 Monument Circle, Indianapolis, Ind.
Ithaca	J. G. Pertsch, Jr.	Geo. F. Bason, Cornell University, Ithaca, N. Y.
Kansas City	F. S. Dewey	Henry Nixon, 509 Mutual Building, Kansas City, Mo.
Lehigh Valley	W. H. Lesser	G. W. Brooks, Pennsylvania Power & Light Co., Allentown, Pa.
Los Angeles	R. A. Hopkins	R. E. Cunningham, 1725 Camden Ave., So. Pasadena, Calif.
Lynn	E. D. Dickinson	F. S. Jones, General Electric Co., Lynn, Mass.
Madison	L. E. A. Kelso	Leo J. Peters, University of Wisconsin, Madison, Wis.
Mexico	E. F. Lopez	H. Larralde, Isabel La Catolica, 33 Mexico, D. F., Mexico
Milwaukee	H. R. Huntley	L. F. Seybold, 446 Public Service Building, Milwaukee, Wis.
Minnesota	A. G. Dewars	J. E. Sumpter, 919-23 Security Building, Minneapolis, Minn.
Nebraska	O. J. Ferguson	C. W. Minard, 509 Electric Building, Omaha, Neb.
New York	H. A. Kidder	H. V. Bozell, Bonbright & Co., 25 Nassau St., New York, N. Y.
Niagara Frontier	J. Allen Johnson	A. W. Underhill, Jr., 606 Lafayette Building, Buffalo, N. Y.
Oklahoma	E. R. Page	C. C. Stewart, Oklahoma Gas & Elec. Co., Norman, Okla.
Panama	L. W. Parsons	I. F. McIlhenny, Box 413, Balboa Heights, C. Z.
Philadelphia	Nathan Shute	R. H. Silbert, 2301 Market St., Philadelphia, Pa.
Pittsburgh	G. S. Humphrey	W. C. Goodwin, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Pittsfield	E. D. Eby	C. H. Kline, General Electric Co., Pittsfield, Mass.
Portland, Ore.	L. W. Ross	J. C. Henkle, Hawthorne Building, Portland, Ore.
Providence	W. P. Field	F. N. Tompkins, Brown University, Providence, R. I.
Rochester	A. E. Soderholm	Earl C. Karker, Mechanics Institute, Rochester, N. Y.

LIST OF SECTIONS—*Continued*

Name	Chairman	Secretary
St. Louis	Fred D. Lyon	Ralf T. Toensfeldt, 311 City Hall, St. Louis, Mo.
San Francisco	R. C. Powell	A. G. Jones, 807 Rialto Building, San Francisco, Calif.
Saskatchewan	E. W. Bull	W. P. Brattle, Dept. of Telephones, Parliament Bldgs., Regina, Sask.
Schenectady	W. J. Davis, Jr.	W. E. Saupe, Bldg. No. 41, General Electric Co., Schenectady, N. Y.
Seattle	E. A. Loew	C. E. Mong, 505 Telephone Building, Seattle, Wash.
Sharon	W. M. Dann	L. H. Hill, Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Southern Virginia	W. S. Rodman	J. H. Berry, 1338 Rockbridge Ave., Norfolk, Va.
Spokane	G. S. Covey	Richard McKay, Washington Water Power Co., Lincoln & Trent, Spokane, Wash.
Springfield, Mass.	R. P. King	J. Frank Murray, 251 Wilbraham Ave., Springfield, Mass.
Syracuse	W. C. Pearce	L. N. Street, College of Applied Science, Syracuse University, Syracuse, N. Y.
Toledo	A. H. Stebbins	Max Neuber, 1257 Fernwood Ave., Toledo, Ohio
Toronto	L. B. Chubbuck	W. L. Amos, Hydro-Elec. Power Commission, 190 University Ave., Toronto, Ont.
Urbana	C. A. Keener	J. T. Tykociner, 300 Electrical Laboratory, University of Illinois, Urbana, Ill.
Utah	John Salberg	D. L. Brundige, Utah Pr. & Lt. Co., Box 1790, Salt Lake City, Utah.
Vancouver	A. Vilstrup	C. W. Colvin, B. C. Elec. Railway Co., Hastings St., Vancouver, B. C.
Washington, D. C.	A. F. E. Horn	L. E. Reed, Potomac Elec. Pr. Co., 14th & C Sts., N. W., Washington, D. C.
Worcester	E. T. Harrop	Fred B. Crosby, 15 Belmont St., Worcester, Mass.
Total 51		

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Arkansas, University of, Fayetteville, Ark	R. McFarland	J. Demarke	W. B. Stelzner
Armour Institute of Technology, Chicago, Ill	H. J. Prebensen	W. A. Dean	D. P. Moreton
Brooklyn Polytechnic Institute, Brooklyn, N. Y	J. C. Arnell	J. H. Diercks	Robin Beach
Bucknell University, Lewisburg, Pa	T. J. Miers	C. A. Rosencrans	W. K. Rhodes
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Carnegie Institute of Technology, Pittsburgh, Pa	G. L. LeBaron	H. E. Ashworth	B. C. Dennison
Case School of Applied Science, Cleveland, O	C. A. Baldwin	A. B. Anderson	H. B. Dates
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Clemson Agricultural College, Clemson College, S. C	B. V. Martin	W. H. Sudlow	S. R. Rhodes
Colorado State Agricultural College, Ft. Collins, Colo	C. O. Nelson	D. W. Asay	
Colorado, University of, Boulder, Colo	O. V. Miller	L. E. Swedlund	W. C. DuVall
Cooper Union, New York, N. Y	F. H. Miller	H. T. Wilhelm	
Denver, University of, Denver, Colo	Earl Reed	R. L. Kuhler	R. E. Nyswander
Drexel Institute, Philadelphia, Pa	E. B. Middleton	W. N. Richards	E. O. Lange
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Michigan, University of, Ann Arbor, Mich	M. H. Nelson	S. L. Burgwin	B. F. Bailey
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Ohio University, Athens, Ohio	N. R. Smith	J. E. Quick	A. A. Atkinson
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Oregon Agricultural College, Corvallis, Ore	H. E. Rhoads	B. E. Plowman	F. O. McMillan
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South Dakota State School of Mines, Rapid City, S. D	J. V. Walrod	C. Allen	J. O. Kammerman
South Dakota, University of, Vermillion, S. D	L. J. Stverak	R. T. Brackett	B. B. Brackett
Southern California, University of, Los Angeles, Calif	J. H. Shideler	E. E. Smith	C. E. Guse
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DIGEST OF CURRENT INDUSTRIAL NEWS

NEW CATALOGUES AND OTHER PUBLICATIONS

Mailed to interested readers by issuing companies

Circuit Breakers.—Bulletin 1643A, 32 pp. Describes the general application of oil circuit breakers. Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa.

Capacitors.—Bulletin GEA-352, 12 pp. Describes capacitors for power factor correction and illustrates concrete savings effected in specific installations. General Electric Company, Schenectady, N. Y.

Transformers.—Bulletins 2052 and 2053, 4 pp. Describe Pittsburgh distribution transformers, single phase and polyphase. Pittsburgh Transformer Company, Columbus & Preble Aves., Pittsburgh, Pa.

Disconnecting Switches.—Leaflets L-25404-8. Describing types RH and RV air-break disconnecting switches. Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa.

Testing Lead Covered Cable.—Bulletin 101, 16 pp. Describes the facilities for testing, inspection and research work on impregnated paper insulated lead covered cable, of the Electrical Testing Laboratories, 80th Street & East End Avenue, New York.

Cable Joints.—Booklet, 16 pp. Describes patented "Metrolatum filled" high tension cable joints, for cable splices from 11,000 to 66,000 volts. The complete material for each joint is supplied in cartons. Metropolitan Device Corporation, 1250 Atlantic Avenue, Brooklyn, N. Y.

Disconnecting Switches.—Bulletin 501. Describes "Fuswitches" and disconnecting switches. Safety factor, rupturing capacity, flashover, construction and other important features are described in detail. W. N. Matthews Corporation, 3706 Forest Park Boulevard, St. Louis, Mo.

Control Apparatus.—A series of two- and four-page bulletins describing d-c. and a-c. manual and automatic starters, rheostats, crane controls, battery charging and testing equipment. Allen-Bradley Company, 286 Greenfield Ave., Milwaukee, Wis.

Safety Switch.—Bulletins 102, 103 and 104 describe the new "Bull Dog SaftoFuse" switch, being built in capacities of 30 and 60 amperes, 250 volts. The product is briefly described as a fuse carrier with switch contacts which may be withdrawn from the receptacle base. When the carrier is in the "on" position the fuse acts to fill the gap between the blade contacts. This moulded composition unit must be fully withdrawn before the fuses are accessible. Mutual Electric & Machine Company, 7612 Jos. Campau Ave., Detroit, Mich.

NOTES OF THE INDUSTRY

The Cutter Electrical & Manufacturing Company, Philadelphia, manufacturers of I-T-E circuit breakers, has removed its New York office from 1170 Broadway to 12 East 41st Street. The New York representatives of the company are W. C. Jessup, M. B. Cutting and R. C. Heyl.

Lapp Insulator Company, Inc., LeRoy, N. Y., announces the appointment of Harris & Butler, Real Estate Trust Bldg., Philadelphia, as district managers for sale of Lapp products. They will serve eastern Pennsylvania, southern New Jersey, Delaware, Virginia and District of Columbia.

The Robert June Engg. Management Company, Detroit, has moved to larger quarters at 2208 W. Grand Boulevard, Detroit, where it now occupies the entire building. This is the organization's fourth move in four years to larger quarters.

Increase in General Electric Orders.—Orders received by the General Electric Company for the first three months of the present year totalled $86,433,658, Gerard Swope, president, has announced. This compares with $83,846,236 for the first three months of 1925, or an increase of three per cent.

New Diesel Engine.—The Foos Gas Engine Company, Springfield, O., has developed a new Diesel engine with a speed range approximately double that of other designs. The engine weight has been reduced to about 50 pounds as against 100 to 300 pounds per horse power in other Diesel engines. It is also novel in being completely enclosed, and the same is true of its lubrication which is completely automatic.

Static Condensers.—The Westinghouse Electric & Mfg. Company has recently developed a new line of static condensers for individual motor application on motor circuits of 220, 440 and 550 volts for two- and three-phase circuits. The new condenser consists of insulation enclosed in a sheet-metal container and a porcelain terminal housing arranged for conduit connections. The condensers will be displayed at the coming N. E. L. A. Convention at Atlantic City.

Largest Steam Turbine for Commonwealth Edison Company.—A cross-compound turbine, to be rated at 90,000 kw. is being built for installation at the Crawford Avenue Station of the Commonwealth Edison Company of Chicago by the General Electric Company. The turbine will consist of two sections, a high pressure element of 35,000 kw. capacity running at 1800 r. p. m., and a low pressure element of 55,000 kw. at 1200 r. p. m. The addition of the new machine will bring the installed capacity of this station up to 327,000 kw. It is expected that the ultimate capacity of the station will reach 750,000 or even 1,000,000 kw.

The National Carbon Company, Inc., New York, has taken over the plant, inventory and good will of the Corliss Carbon Company, Bradford, Pa., and has also purchased the battery business of the Manhattan Electrical Supply Co., New York, N. Y. The latter purchase includes the battery plants at Jersey City, N. J., and at Ravenna, O., trademarks, patents, etc. The trademark "Red Seal" under which the Manhattan batteries have been advertised will be continued. J. F. Kerlin, president of the Corliss Carbon Company, and formerly assistant general sales manager of the National Carbon Company, Inc., will assume the position of vice-president of the latter company and have complete charge of the sale of all carbon products.

The Wm. Cramp & Sons Ship & Engine Building Company, Philadelphia, has recently secured hydraulic machinery contracts for seventeen units totalling nearly one-half million horse power. The turbines, water wheels and other hydroelectric devices comprising these orders will be installed in Brazil, Japan, Canada and the United States. One contract calls for a 56,000 h. p. impulse wheel, the highest powered of its kind intheworld.

Two 5000 h. p. Moody propeller turbines are intended for the Maribondo Development in Brazil, and two 29,000 h. p. turbines for the Nippon Electric Company, Japan. Two 31,000 h. p. and one 25,000 h. p. units are to be installed in the Norwood Development of the Carolina Power & Light Company. The 56,000 h. p. impulse wheel is being built for the Southern California Edison Company in the San Francisco plant of the Pelton Water Wheel Company, which is owned by the Cramp Company. Two 30,000 h. p. impulse wheels have been ordered by the Feather River Power Company.

The Dominion Engineering Works, Ltd., Montreal, Canadian licensee of the Cramp Company, has secured contracts for three 30,000 h. p. units and three 21,000 h. p. units for the Canadian International Company, and one 28,000 h. p. Moody propeller unit for the Manitoba Power Company.